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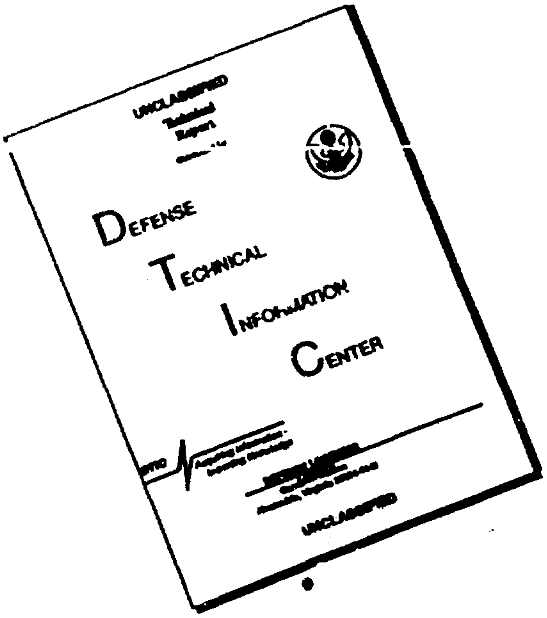

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Integrated Seawater Sampler and Data Acquisition System Prototype: Final Report

by

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Technical Report

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ABSTRACT

This report documents the work performed by the Woods Hole Oceanographic Institution (WHOI) and the Battelle Memorial Institute from August 1988 to December 1992 in the NSF sponsored development of an Integrated Seawater Sampler and Data Acquisition Prototype. After a 6-month initial design study, a prototype underwater profiling unit was designed and constructed, containing the water acquisition subsystem, CTD and altimeter, control circuitry and batteries. A standard WHOI CTD was adapted for use in the underwater unit and was interfaced to the underwater controller which had a telemetry module connecting it with a deck control unit. This enabled CTD data to be logged in normal fashion on shipboard while additional commands and diagnostics were sent over the telemetry link to command the underwater unit's water sampling process and receive diagnostic information on system performance.

The water sampling subsystem consisted of 36 trays, each containing a plastic sample bag, the pump and control circuitry. The sample bags, initially sealed in a chemically clean environment, were opened by pumping the water out of the tray, thus forcing water into the bag by ambient pressure. The command system could select any bag, and control the water sampling process from the surface with diagnostic information on system altitude, depth, orientation and cable tension displayed in real time for operator information.

At sea tests confirmed the operation of the electrical and control system. Problems were encountered with the bags and seals which were partially solved by further post cruise efforts. However, the bag closing mechanism requires further development, and numerous small system improvements identified during the cruises need to be implemented to produce an operational water sampler. Finally, initial design for a water sampler handling and storage unit and water extraction system were developed but not implemented. The detailed discussion of the prototype water sampler design, testing and evaluation, and new bag testing results are presented.

INTRODUCTION

Scientific Background

Back in the days of the METEOR Atlantic Expedition (1925 to 1927) and the International Geophysical Year (IGY) survey of the Atlantic (1957 to 1959), hydrographic investigations were conducted using discrete, small-volume water samplers and reversing thermometers. Temperature, salinity, and pressure measurements typically were obtained from a limited number (say 10 to 25) of "standard" levels at each station. Vertical resolution was poor because the weight of the sampling bottles limited the number of sample levels that could be obtained from a single cast, and multiple casts meant longer station times and horizontal sampling errors due to ship drift.

Chemical oceanography during the early hydrographic investigations generally was limited to analyses of dissolved oxygen, pH, and selected nutrients; all of these analyses were conducted using samples drawn from the same bottles used for the physical measurements. Thus, the early chemical and physical oceanographers were mutually compatible, at least in terms of sampling operations. This compatibility was lost in the early 1960's, however, with the introduction of the STD and CTD in situ profiling systems. Physical oceanographers could now obtain data on vertical scales of centimeters, and only a limited number of small-volume water samples were required for calibration of the electronic sensors. Attaching a large number of sample bottles to the CTD wire for chemical sample collection became a nuisance to the physical oceanographer because it meant additional time for handling, slower descent rates due to increased drag, and longer station times due to both factors. To make things worse, the state of the art in chemical oceanography was progressing rapidly and new techniques were being developed to accurately measure trace concentrations of dissolved gases and metals in water samples. As the analytical procedures improved, the chemists' detection levels were soon limited by the volume of the water sample, rather than by the laboratory instrumentation.

During the mid-1970's, the Geochemical Ocean Sections Study (GEOSECS) investigation of the Atlantic, Pacific, and Indian Oceans was undertaken by the Woods Hole Oceanographic Institution and Scripps Institution of Oceanography. The primary objective of this global survey was to measure radioisotopes and other geochemical tracers, in conjunction with high-precision measurements of temperature, salinity, and density in both continuous and discrete-sample profiles. In some ways, GEOSECS was the epitome of incompatibility between physical and chemical oceanographers. The CTD was the primary profiling system for analysis of water mass characteristics, but repeated casts with two 12-position rosette samplers had to be made on each station to collect the 30-liter volumes of water that were required from each of 50 sample levels.

These multi-cast stations required the better part of a day, rather than the four to six hours that was standard for CTD profiles. To the physical oceanographer, this meant drastic reductions in the number of stations that could be occupied during each cruise leg, as well as for the entire program. This reduction resulted in relatively sparse horizontal sampling and serious spatial aliasing by mesoscale variability. In perspective, the GEOSECS program provided interesting, high-quality information on large-scale geochemical variability throughout the world oceans, but its value to the physical oceanographer was far less than the METEOR and IGY investigations which provided better horizontal resolution.

In 1986 and 1987, a scientific plan for the World Oceanic Circulation Experiment (WOCE) Hydrographic Program was developed for the collection of high-accuracy hydrographic and tracer data from the global oceans. The major

component of the WOCE Hydrographic Program is Core Project 1, consisting of a one-time occupation of transects in all the world oceans, with nominal 30 nautical mile (nm) station spacing along transects. Additional stations were added in boundary-current regions and in the vicinity of major topographic features.

The proposed survey plan for the WOCE Hydrographic Program was intended to provide CTD data on horizontal scales sufficient to resolve the large-scale circulation within ocean gyres, without being severely aliased by the mesoscale variability. For salinity calibration, small-volume water samples were required from 24 depth levels at selected stations.

A WOCE Hydrographic Program chemical tracer study was to be made in conjunction with the CTD profiling operations, but only a subset of the CTD stations would be sampled for chemical analyses. The primary chemical measurements included oxygen, nutrients, freon, tritium, ^{3}He, ^{14}C, and CO_2. Because each of these chemical analyses (with the possible exception of ^{14}C) requires only a small volume of sample, 10-liter sample bottles were sufficient for salinity calibrations and tracer studies. These "small volume" sampling requirements differ greatly from the large (>250 liter) volumes that would be required if ^{226}Ra, ^{228}Ra, ^{85}Kr and ^{39}Ar were added to the suite of routine tracer measurements during the WOCE Hydrographic Program. Because large-volume sampling would require an additional five to eight hours per station, these casts would be spaced every 300 nm along transects, or at every 10th CTD/small-volume station.

The immediate need for the next-generation seawater sampler and CTD data acquisition system was, therefore, to satisfy the sampling requirements of the WOCE Hydrographic Program. The system must fulfill the requirements of both the physical oceanographers (high-quality CTD profiles with rapid profiling rates) and the tracer chemists (uncontaminated 10-liter water samples from up to 36 sample levels per station), thus requiring only one vertical profile per station. These and other sampling requirements of the WOCE Hydrographic Program are presented in a report [1], which summarizes a U.S. Workshop held in January 1987 to discuss the WOCE Hydrographic Program.

Technical Issues

Although present water sampling systems, such as CTD profilers interfaced to rosette samplers supporting Niskin or Go-Flo bottles, satisfy the sampling requirements of most ocean research programs, the extensive survey plans and stringent contamination issues of the WOCE Hydrographic Program necessitated the development of a new sampler with improved capabilities. The major WOCE Hydrographic Program operational requirements, the general sampling considerations of the WOCE physical and chemical oceanographers and the initial logistic considerations are next discussed in some details.

Operational Requirements of the WOCE Hydrographic Program

The major WOCE Hydrographic Program requirements for the next-generation "small volume" water sampler were speed and data quality. The basic need was for a 36-place water sampler interfaced to a state-of-the-art CTD profiling system that would allow 6000-m profiles in significantly less time than the 4 hours that is standard for CTD profiling systems having 24-place rosettes with one-liter bottles. For the suite of tracers to be analyzed as part of the WOCE Hydrographic Program, it was a requirement that sample volumes be 10 liters each, rather than the one liter normally collected for a small volume-programs using standard rosette systems. A few physical oceanographers (e.g., M. McCartney at WHOI) have averaged two hours per station for 6000-m profiles

using 24-place rosette samplers with one-liter bottles, but the increase from one to ten liter samples and from 24 to 36 bottles would certainly have a major effect upon station time using present technology. The optimum 36-place, 10-liter sampler would thus be one that could average 2 m/sec, and thereby complete a 6000-m profile in less than two hours.

Although the profiling winches on most UNOLS vessels can achieve speeds of 2 m/sec, the limiting factor with present water sampler technology is surface area and drag caused by the 10-liter bottles. Large samplers can be raised at speeds approaching 2 m/sec, but their excessive drag often limits their terminal velocity to 0.5 m/sec or less for downcasts. One approach for the structural design of the new water sampler was to focus on reducing the drag of the total underwater unit (water sampler, CTD sensor package, and frame). Addition of mass to the underwater unit would also be considered as a means of increasing terminal velocities, but major reductions in drag must be accomplished before changes in mass can significantly improve terminal velocities.

Secondary factors that affect total time on station include the time for deployment and recovery, and the time required to collect a water sample at each of the 36 depth levels if the instrument package must be stopped during sample collection. With a semiautomated deck handling system for launch and recovery of the water sampler package, it would be possible to save ten minutes or more per station compared to present launch/recovery techniques, which often consist of deck personnel using tag lines.

Another time-saving option considered for the WOCE Hydrographic Program was the addition of a second platinum resistance thermometer within the CTD underwater units. This would effectively eliminate the need for deep-sea reversing thermometers for calibration of the electronic temperature sensors. The CTD software could be modified to monitor both PRTs, and to sound an alarm if their temperature readings differed by more than some prescribed tolerance, thus indicating a problem with one or both sensors. This real-time equipment surveillance has two major advantages over classical thermometric techniques: 1) equipment problems are detected while the instrument is still in the water rather than with the system on deck, or underway to the next station or even after the cruise has been completed, and 2) the significant time for "soaking' the thermometers is eliminated, thus saving 10 to 30 minutes per station, depending upon the number of calibration levels.

Without the need for reversing thermometers, the only time required at each sample level is that needed to adequately flush the water sample container and/or collect the sample. If 30 seconds were required at each of 36 sample levels, this would translate into 18 minutes per station. This is a significant (and possibly detrimental) time requirement. Furthermore, motion compensation may be required to ensure that each water sample is collected within ±5 m of the desired sample level. In light of this sampling requirement, the optimum water sampler would allow for collection of water samples without stopping the winch. In addition to saving significant time, this would also reduce oxygen measurement errors, which are compounded by changes in flow rate due to the slow response of present membrane sensors.

Physical Oceanographic Considerations

For the physical oceanographer, the goal of the WOCE Hydrographic Program was to obtain high-quality CTD profiles, from the surface to the ocean floor, at 30-nm intervals along major ocean transects. The resulting density data would then be used for geostrophic calculations of transport through individual sections as well as for input to a variety of ocean and gyre-scale circulation models. Conservative quantities such as temperature, salinity, and computed potential vorticity could also be used to deduce advection,

mixing, and the relationship between the general circulation and the observed distribution of chemical tracers. Because the major emphasis of the WOCE Hydrographic Program is on the large-scale circulation, no attempt was to be made to resolve smaller-scale processes such as microstructure, internal waves, and sub-mesoscale eddies. At winch speeds of 2 m/sec and CTD sampling rates of 24 Hz, the maximum vertical sampling resolution would be limited to roughly 8 cm, which precludes meaningful microstructure studies. Likewise, analyses of internal waves and eddy phenomena would require intensive temporal and spatial sampling, respectively, which is not possible within the stringent time constraints of the WOCE Hydrographic Program.

From the viewpoint of the CTD data quality, the most important consideration in the design of the improved water sampler and CTD data acquisition system was that the hardware configuration not disturb the water flow immediately ahead of the CTD sensors. Present systems are configured with the CTD sensor package situated beneath the water sampling device (e.g., rosette sampler) so that good quality CTD data are acquired when the sensor package is descending monotonically. In this "sensor down" configuration, CTD data quality is degraded when the sensors lay in the wake of the water sampler. This condition occurs 1) during the ascent (upcast), 2) when the water sampler is stopped at a depth level for collection of samples, and 3) during rough sea conditions when the vertical oscillations of the vessel temporarily halt the smooth downward progress of the CTD. The situation is reversed if the CTD is situated above the water sampler and oriented "sensor up"; in this case, good quality CTD data would be acquired only on the upcasts.

This "sensor up" configuration becomes moot if there exists an improved profiling system capable of acquiring good quality CTD data at descent rates of 2 m/sec, and of collecting water samples with little or no stopping during the descent. In any event, it is not desirable to sample water in the wake of the profiling wire, a phenomenon which occurs when taking an upcast.

Collection of the calibration water samples concurrently with the acquisition of the good quality CTD data is also a major concern to the physical oceanographers. Numerous studies have shown that calibration data exhibit significant errors when the water samples for salinity and oxygen calibration are collected on the upcast, rather than concurrently with good quality CTD downcast data. This is due primarily to horizontal variations in the property fields (the upcast profile is displaced laterally from the site of the downcast due to ship drift), but any hysteresis in the temperature response of the pressure sensor of the CTD would also lead to unavoidable vertical displacement between upcast calibration samples and downcast CTD readings.

The basic design of the Niskin bottle causes water leakage problems when water samples are collected on the downcast. To alleviate this problem, investigators at the Woods Hole Oceanographic Institution modified several Niskin bottles by adding rubber diaphragms to compensate for the change in volume after the bottle has been closed. The bottles were used during two cruises with reasonable results, but the increased maintenance problems associated with the rubber diaphragms outweighed the gain, and unfortunately the downcast sampling with Niskin bottles was dropped. In a report on measurements of salinity and oxygen at the Woods Hole Oceanographic Institution, Knapp and Stalcup [1] make the following statement on in situ sampling bottles: ***"As presently configured the General Oceanics Rosette is bulky, awkward to use and is not as reliable as we would like... Sometimes the Niskin bottles trip early, fail to trip, or trip late and close at a shallower depth...The oceanographic community sorely needs a water sampler that addresses these shortcomings."***

One last problem with present rosette samplers is that, when 1 or 2 conductor cables are used, collection of CTD data is interrupted each time a water sample bottle is tripped, and the missing data cause problems during subsequent data processing. Interrupting the power to the CTD also creates spurious oxygen data when the power within the oxygen sensor is reduced during the firing of the rosette.

Chemical Tracer Considerations

DISSOLVED GASES: Maintaining the integrity of dissolved gases in water samples is a critical aspect of obtaining water samples for geochemical analyses in the WOCE Hydrographic Program. Many of the important WOCE tracers are gases (oxygen, CO_2, ^3HE, and freons) that are sensitive to gas or vapor exchange (in the case of tritium and ^{14}C). The primary problems with standard Niskin sample bottles are twofold: the long "incubation time" of the closed Niskin bottle in the water column and on deck, and the time that is spent once the Niskin is vented at the commencement of sampling. The incubation time can certainly be minimized by the design of a rapid profiling and recovery system; however, the most important factor in gas sample contamination is venting.

A recent study by Takahashi et al. [2] indicates that gas concentrations are significantly affected within 15 minutes of the time that the Niskin bottle is opened, and that the degree of effect is primarily a function of head space inside the bottle. This problem can be avoided with the use of a deformable, collapsible container that can be removed from the water sampler immediately after recovery. Direct transfer of the water sample container into an insulated carrier as it is removed from the water sampler would also minimize thermal diffusion due to rapid temperature changes. Once inside the shipboard laboratory, the sample containers could be mounted on a sampling manifold for careful transfer of the sampled water.

Analysis of freon concentrations in seawater samples promises to be an important component of the WOCE Hydrographic Program because recent studies have shown that anthropogenic compounds such as freon are useful time-dependent tracers of ocean mixing and circulation processes. At present, the limits of freon detection in 30 cm^3 of seawater are about 0.005×10^{-12} mol/kg of seawater, or 0.05 g/km^3 of seawater. At these concentration levels, even trace amounts of freon from shipboard sources and sampling containers can severely contaminate seawater samples. On a number of hydrographic sampling programs, part of the contamination problem has been related to the release of freon into the water samples from the walls and O-rings of the Niskin bottles used to collect the water samples.

Materials and sealing techniques for the sampling system must be evaluated carefully if such a system is to be used to collect seawater samples for the diverse suite of gases, nutrients, and trace metals that represent the core of the WOCE tracer program. If reliable freon analyses are desired, the materials chosen for construction of the water sample containers must be compatible with ultra-low-level measurements of these compounds in seawater. If the flexible water containers will not be flushed with surrounding seawater before each sample is collected, the containers must initially be free of any freon, and must remain so until the water sample is captured.

The walls of the material must not absorb or adsorb freon from the water sample, and must also prevent freons or other gases of interest from diffusing into the container between the time of preparation and usage. Once the container is filled with the seawater sample, gas exchange between the atmosphere and the sample must be minimized, preferably through the use of carefully designed equipment used for the sample transfer.

TRACE METALS: It has been well established in the past decade that the quality of seawater samples to be used for trace metal analysis is highly dependent on the type and composition of the water sampling equipment, and control of potential shipboard sources of contamination. Investigators have demonstrated that the following precautions are necessary in order to ensure uncontaminated water samples for trace metal analyses:

- No exposure of the internal surfaces of the sample container as the sampler passes through the sea, especially in close proximity to the research vessel.
- Isolation of the sampler from steel lowering cables.
- Construction of the water sample containers from materials having low metals content.
- Control of the sample transfer environment through the use of Class-100 clean benches or vans.

All the scientific issues, both physical and chemical, mentioned above, were incorporated as stringent requirements and addressed in the evaluation of the water sampler.

Logistic Considerations

In addition to the various scientific considerations outlined above, there were other logistical and operational factors to be considered for the design of a system meeting the general requirements of the Ocean Sciences Division of NSF. These included the following:

- The ability to safely conduct profiling operations in moderate to rough seas and during wind speeds up to 40 knots.
- Protection from loss of equipment during handling operations and damage while stowed on deck.
- High reliability with minimal requirements for at-sea maintenance.
- A well-engineered system that can be manufactured at reasonable costs, such that the UNOLS fleet and foreign research vessels can be upgraded over the next five years.

PROTOTYPE WATER SAMPLER DESCRIPTION

General Description

The primary objective of this project was to develop a prototype of the next-generation water sampler that will be used for the WOCE Hydrographic Program. As discussed in Section 1, the technical specifications must meet the sampling requirements of WOCE, but broader sampling issues were also addressed to ensure that the system will be useful for other global geoscience programs that may develop over the next few decades.

In accordance with the initial NSF solicitation, the fully integrated seawater sampler and data acquisition system will have four major components:

1. The underwater unit consists of four major subsystems (see Fig. 1):

- The structural assembly of the underwater unit includes the internal frame, fairing, syntactic foam, and an electro-mechanical termination.
- The sea water acquisition subsystem includes the pump, flow controls, and drawers for water sample containers.
- The CTD data acquisition subsystem includes the standard CTD profiling package, additional sensors, and bottom-finding altimeter.
- The control, monitoring, and telemetry subsystem receives sampling requests from the surface, actuates sampling, and sends information from the CTD and altimeter to the surface.

2. The deck control unit consists of the control computer and associated software, the CTD control unit, the water sampler control unit, and additional control units for the winch and motion compensator.

3. The handling and deck stowage system consists of the winch and cabling, the motion compensator,and the integrated launch/recovery and stowage system.

4. The shipboard water sample transfer system consists of equipment to transfer the water sample from the underwater unit into the laboratory, and apparatus for removing water from the sample containers.

The underwater unit is the instrument package attached to the end of the electro-mechanical lowering cable for collection of water samples and CTD data. The design of the improved seawater sampler is based upon the need for rapidly acquiring uncontaminated water samples for analysis of geochemical tracers, in addition to precise measurements, using in situ sensors, of temperature, salinity, density, and dissolved oxygen. To meet this basic objective while satisfying the sampling requirements of global geoscience programs such as WOCE, the underwater unit must meet the following operational requirements:

- Average profiling speeds (descent and ascent) must reach 2 m/sec.
- The water sampler must be capable of collecting 36 seven-liter, uncontaminated water samples during the descent and/or ascent.

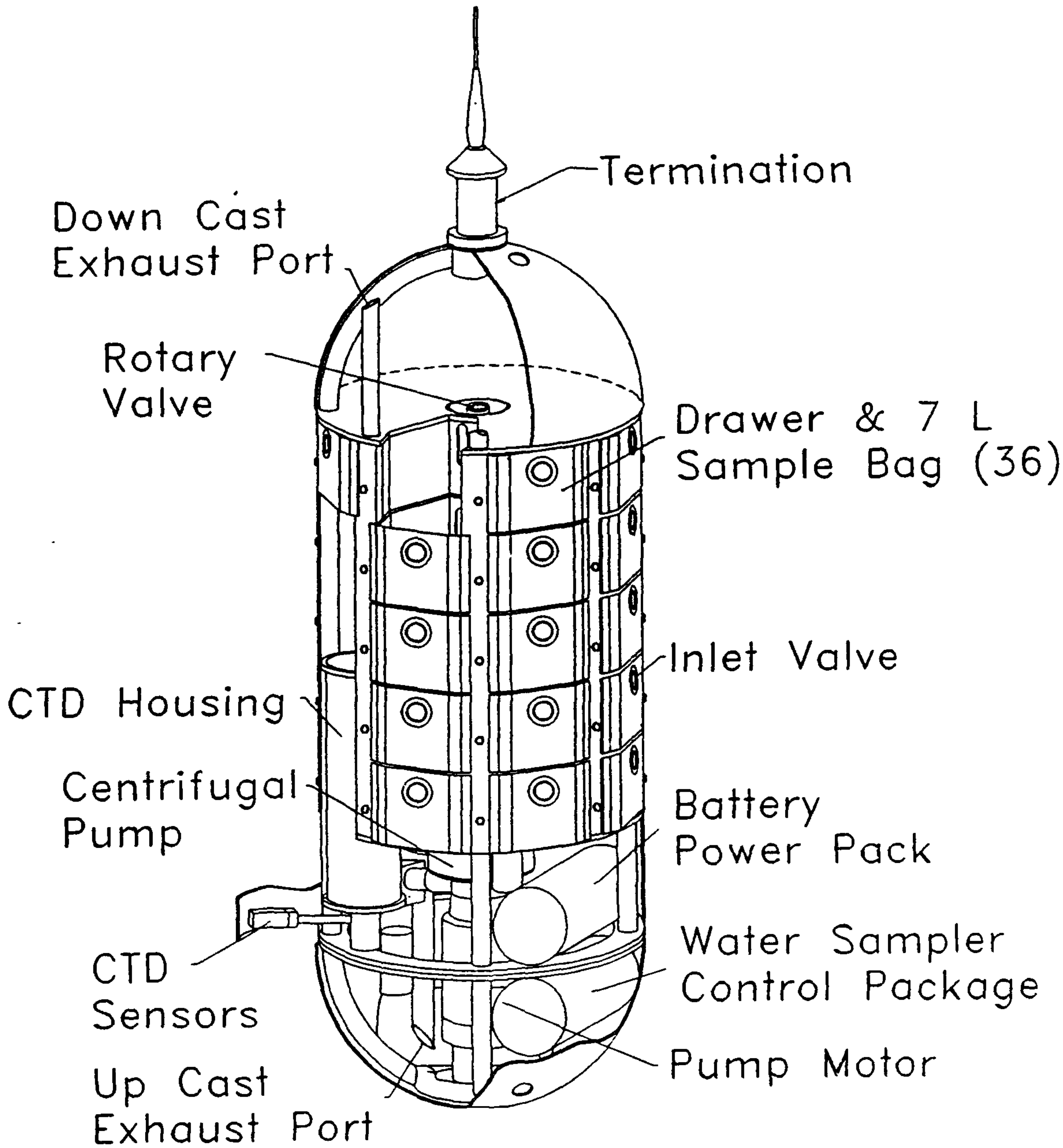


Figure 1: Schematic View of Underwater Unit

- The underwater unit must accommodate CTD profiling systems from leading manufacturers.

- The underwater unit must accommodate a bottom-finding altimeter that can be electronically interfaced to the deck control system.

The four subsystems in the underwater unit are discussed in detail in the following four sections.

Structural Assembly

Design Rationale

The structure and termination of the underwater unit consists of an internal frame to support the payload (i.e., water sampler unit, CTD and other components), an outer fairing to reduce drag during profiling, syntactic foam for flight stability, and an electromechanical termination to attach the underwater unit to the lowering cable.

The sampler was designed to perform rapid profiles while collecting high quality sea water samples. Essential features of the design included:

- Design of sample drawers, fairings and batteries to minimize turn-around time between casts.

- Low maintenance.

- Quick flooding when the sampler is launched.

- Stability, statically and dynamically, at maximum lowering and retrieval speeds.

- The terminal velocity of the sampler must exceed the terminal velocity of the cable and the downward velocity of the head sheave when the ship rolls.

- The sampler must be compact and streamlined in order to attain the fast payout and retrieval speeds specified.

Basic Configuration

The design was a difficult exercise in configuration management. A large number of components which evolved rapidly in separate locations, finally were fitted together in a very cramped space. The tightest feasible packaging produced a sampler 80 inches in length and 33.5 inches in diameter. This results in an aspect ratio of 2.38:1. The shape is cylindrical with hemispherical ends.

The frame structure was designed to withstand the maximum expected dynamic load without flexing. Flexure could cause the rotary valve to bind up, or the seals between the drawers and the rotary valve to leak. The tensile strength of the frame is in excess of 25,000 pounds at the weakest point.

The initial plan in the working prototype called for a titanium frame. Early on it was decided to make the prototype package out of schedule 40 steel to ease the numerous changes and iterations that are always part of a development effort of this complexity. All steel components were chosen to

match commercially available titanium shapes for later translation to the working model frame.

The frame is composed of 1-1/2 inch schedule-40 steel pipe and steel plates. Four bent pipes join the top plate to the apex of the sampler with its tension cell and grabbing fixture. Eight pipes extend from the top plate to a plate located at the bottom of the drawer section; four continue through to a thin annular ring located at the midpoint of the lower section. A second annular ring bolts up to this and has three curved pipes joining at the bottom at a rolled pipe ring, 14 inches in diameter.

The upper hemispherical section is covered with a fiberglass shroud. Four syntactic foam blocks molded as quadrants of a hemisphere fill most of the space. Cavities and rabbits were carved into the foam so that it would fit around the four structural pipes and the rotary position and home sensors. A one half inch thick steel plate separates the upper section from the sampler drawer section.

The sampler drawer section has steel plates top and bottom and eight evenly spaced pipes around the periphery. The Battelle rotary valve occupies the center of this section, and is held in place by eight ladderlike frames that also support the sample drawers. The drawers fit into the ladders in five layers of eight drawers each. A stainless steel strip is bolted to the outside of each of the eight pipes and has backing clips for 1/4 turn fasteners. The mating part of the 1/4 turn fasteners are attached to the sample drawers; they provide a positive, but quick, method of mounting and dismounting the samples. Four drawers are omitted in one section to allow room for the installation of a Neil Brown Mark IIIB CTD or a Seabird CTD.

Below the sample drawer section the lower section contains the operating mechanisms and instrumentation. The pump motor used to provide suction through the rotary valve to the sample drawers is located in the center of the volume, with the pump impeller housing above it. The rotary valve driving sprocket, a flow sensor and a rotary joint are between the top of the pump and the bottom of the rotary valve.

The rotary valve is driven by a stepper motor in an oil-filled housing that drives a small sprocket. The torque is transmitted from the sprocket on the stepper motor to the sprocket on the rotary valve by a wire rope and urethane timing chain. A spring loaded idler sprocket was added to help reduce the rotary indexing error caused by unequal chain tension on the tension and return sides of the large sprocket.

The exhaust of the pump was directed to a Battelle housing containing a three-way valve. One side of the three-way valve was plumbed out the bottom of the bottom shroud to leave the pumped water in the wake on the upcast. The other port of the three-way valve was plumbed into one of the vertical pipes so the water was forced to exit out the top of the sampler on the downcast.

Two type 7075-T6 aluminum battery cases, 7.5 inches in diameter and 19 inches long, were attached on fiberglass channels to the top of the top annular ring. Two similar channels were installed below the bottom annular ring to support two pressure cases, 7.5 inches diameter by 20 inches long, containing the attitude sensing package and the control and telemetry electronics. The cases were fastened to the fiberglass racks with quick release scuba tank bands to minimize turnaround time. An acoustic altimeter was packaged vertically in the lowest section such that the transducer is aimed out a hole cut into the lower hemispherical fiberglass shroud.

The short section between the bottom of the drawers and the annular rings was shrouded by a band of polyethylene sheeting. This band was also held on by 1/4 turn fasteners for easy access to the batteries.

The sampler's empty weight in air is 1500 pounds; when full of 36 7-liter sampled, the weight is 2060 pounds; when immersed in water, it weighs is 500 pounds.

The water sampler was designed to be statically stable. syntactic foam flotation in the top of the frame provides buoyancy, the bottom of the frame contains the heaviest components (pressure cases and batteries). The center of gravity is located 41.44 inches above the bottom end. The center of buoyancy is located 49.77 inches above the bottom. This results in a righting moment that can be expressed as

$$500 * (49.77-41.44)\sin(\text{theta})$$

where theta is the tilt angle, and the righting moment is expressed in foot-pounds. The horizontal centers of gravity and buoyancy were kept as close as possible to the axis of symmetry.

Fabrication

The frame was fabricated in the WHOI welding shop. The pipe sections that required bending to an exact curvature were ordered from an outside vendor. The four pipe sections that frame the top of the sampler meet at a machined steel boss. The boss is designed to accept the tension cell below it with the strength member passing through the center. The termination clevis is fastened to the top eye of the load cell strength member rod with a pin. A two-part steel device clamps over the top flange on the boss and the termination, and has a mushroomlike top section so that it can be grabbed by the proposed handling system. An additional two-part weldment clamps over this mushroom and provides two loops for handling lines for deployment and recovery on the test cruises when the handling system was unavailable.

These four pipes extend through the sample drawer section and down to the top annular ring. Steel strips one eighth inch thick by three inchs wide are welded to conform with the outside of the pipes in the top section and to provide a place to attach the top shroud. The top section ends at a one half inch thick steel plate. This plate is drilled to provide mountings for the ladders in the section below, the top guide for the rotary valve, the home position, and rotary position sensors and the four syntactic foam blocks. Four additional pipes are welded to the bottom of this plate to make up the eight required for the drawer supports. The tops and bottoms of these pipes were drilled through the plates and a number of large diameter holes were drilled in this plate to facilitate flooding when the instrument is first placed into the water.

One of the eight pipes in the sample drawer section is slotted from top to bottom to facilitate running cables past the drawer section. A Stainless steel clamp fits into one of the eight sections to hold the CTD.

The bottom plate is also 1/2 inch thick steel. It is drilled to mount the pump bracket, the rotary valve stepper motor, the three-way valve, the idler unit and a guard for the CTD. Additional flood holes are included here as well.

Seawater Acquisition Subsystem

Description of Water Sample Acquisition

The seawater acquisition subsystem is contained within the underwater unit, and is designed to:

- Collect 36 seven-liter, uncontaminated water samples during descent or ascent for chemical oceanographic analysis as well as for physical oceanographic verification of the CTD data on command from the surface.

- Allow sample volumes to be varied between one and seven liters.

- Collect the water sample within ±5 meter of the desired sample depth with the underwater unit moving at 2 m/sec.

- Collect water samples without interfering with the collection of CTD data.

- Provide on-deck confirmation of water sample collection.

The design of the seawater acquisition subsystem uses an evacuating pump system to fill closed, evacuated water sample containers. During a cast, the seawater acquisition system operates in the following manner. When the underwater unit is first launched, the sample drawers flood with surface water. This initial fill of water is the working fluid for the pump during subsequent casts, when each sample container is inflated. The working fluid contained in the free-flooding portion of the water sampler drawer is never allowed to contact the interior of the sample containers, nor does it mix with the sample water as it enters the sample containers. (After flooding, the system is as shown in Fig. 2a).

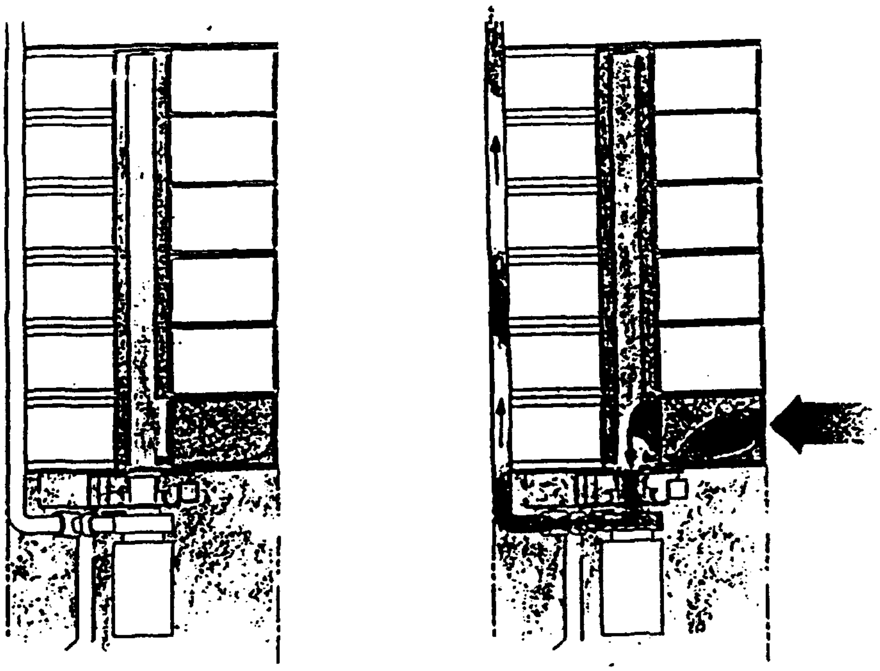
A rotary selector valve connects one sample drawer at a time to the suction of the pump. When the desired sample depth is reached, the pump is turned on, which applies a suction to the outside of the sample container. A valve on the sample container opens, and sample water is drawn through into the evacuated container. The pump runs for five seconds or less, drawing seven liters of seawater sample into the container while drawing an equivalent volume of working fluid out of the drawer around the filling container. In this way, samples are moved directly from the sea to the sample containers (Fig. 2b).

Contamination is largely minimized by drawing water directly from the sea into the sample container. Fluid crosstalk is eliminated by careful design of the hydrodynamics of the exterior of the entire underwater unit, and in particular the exterior portions of the drawer and closure valve. Reduced contact between the sample and the collection equipment minimizes equipment contamination,. Uncontaminated collection on both downcast and upcast is enabled by redirecting the pump discharge, always venting it in the wake of the underwater unit so it cannot be drawn back in during sampling.

After the pump is stopped, the flow stops. When the flow stops, the closure valve seals the water sample from the ambient sea water (Fig. 2c). Shortly after the pump has stopped, the rotary sample selector valve is indexed to the next sample drawer to wait for the next collection command.

The subsystems which make up the seawater acquisition subsystem (Fig. 3) can be divided into sample containers, framing, and flow controls. The framing includes the drawers which hold the sample containers and the supports retaining them in the underwater unit. The flow controls are composed of the rotary sample selection valve, the sample confirmation mechanism, and the pumping system used to fill the sample containers.

SAMPLE CONTAINERS: The sample containers are flexible tri-laminate plastic bags bonded to an inlet valve subassembly. Being flexible, the container automatically is pressure compensated. The bag is designed with a minimum of nine-liter absolute capacity. With a maximum seven-liter sample,



2a — Before Collection

2b — Sample Collection

2c — After Collection

Figure 2: Operating Principle of Water Collection

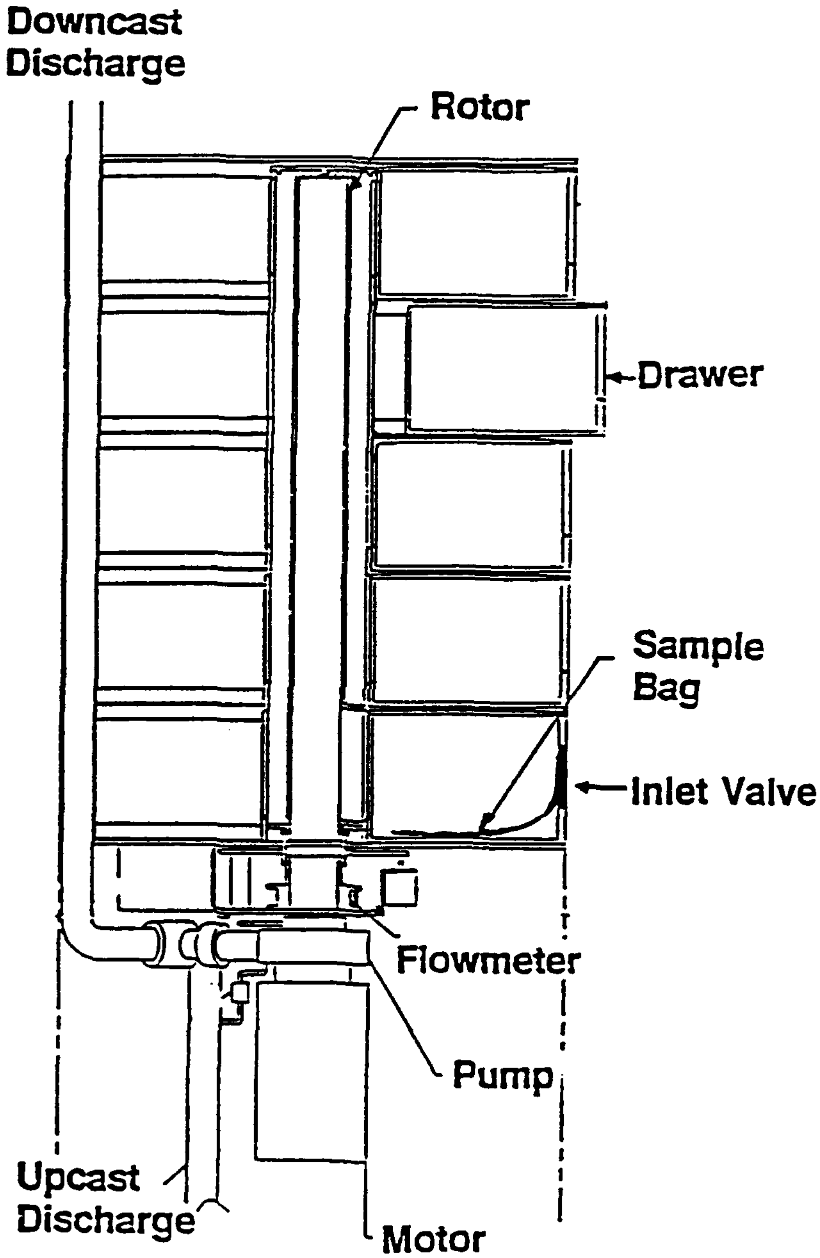


Figure 3: Subsystems of Water Acquisition System

the bag then has 28% excess capacity for volumetric expansion, more than enough to compensate for a sample brought to the surface from a 6000-m depth.

The inlet valve subassembly (Fig. 4) has a body plate with valve and transfer port. The intake to the sample container is through the closure valve, which is vented directly to the sea at the exterior of the underwater unit. Pumping the drawer container generates a suction inside the container, applying an opening force to the closure valve. This allows water to enter the container. The transfer port is for accepting the transfer probe when subsampling water from the container after the cast.

During Phase I of the development, a variety of closure valve concepts were considered and evaluated. On the basis of simplicity, reliability, and cost, the magnetically latched disc valve shown in Fig. 4 was selected for use. The key features of this valve design are <u>simplicity</u>, <u>quick operation</u>, a <u>passive latching</u> capability feature to resist wave slap, and a <u>planar outlet configuration</u> for enhanced container protection.

The valve is inherently simple and reliable because it has only one moving part. It showed promising results during laboratory testing. The valve disc is held against its seat by an annular permanent magnet. When the sample container is subjected to pump suction, the disc is pulled away from the magnet and arrested by mechanical stops after a short opening stroke. When the pump is switched off, there is sufficient magnetic force to reseat the disc without springs or other restoring devices which might interfere with the container, reduce reliability, or introduce sample contamination. The metal parts and magnet are coated with materials which are non-corrosive and non-contaminating to the sample.

Seawater Acquisition Subsystem Hardware

DRAWERS: The 36 drawers of the seawater acquisition subsystem unit are located in the center, cylindrical section of the underwater unit. This cylindrical section is about 92.4 cm (36.4 in) tall by 83.8 cm (33 in) in diameter. The drawers are laid out in five levels (Fig. 3), each about 17.8 cm (7 in) in height. Each level is divided into eight individual compartments, each one occupying a 45° segment of the level. A section showing radial divisions is given in Fig. 5. This provides 40 compartments, but four of the compartments are occupied by the CTD pressure housing. The volume of each drawer is 8.4 liters, thus providing ample room for the sample containers.

The sample containers must be moved into the drawers before they are to be used. First, the stowage bag which contains 36 sample containers is opened. The sampling containers are slid into matching slots in the empty drawers. If necessary, the sample containers can be nitrogen purged and re-evacuated. Lastly, the drawer lid is placed in grooves of the drawer bottom (Fig. 6).

FLOW CONTROLS:

ROTARY VALVE. The function of the rotary valve is to select one and only one of the 36 sample containers to be filled at any given time. The rotary valve assembly is composed of an outer fixed tube, an inner rotor, and an indexing mechanism.

The rotary valve assembly is positioned on the centerline of the underwater unit, between the upper and lower bulkheads. It is held in place by the eight structural frames which also hold the sample drawers in place.

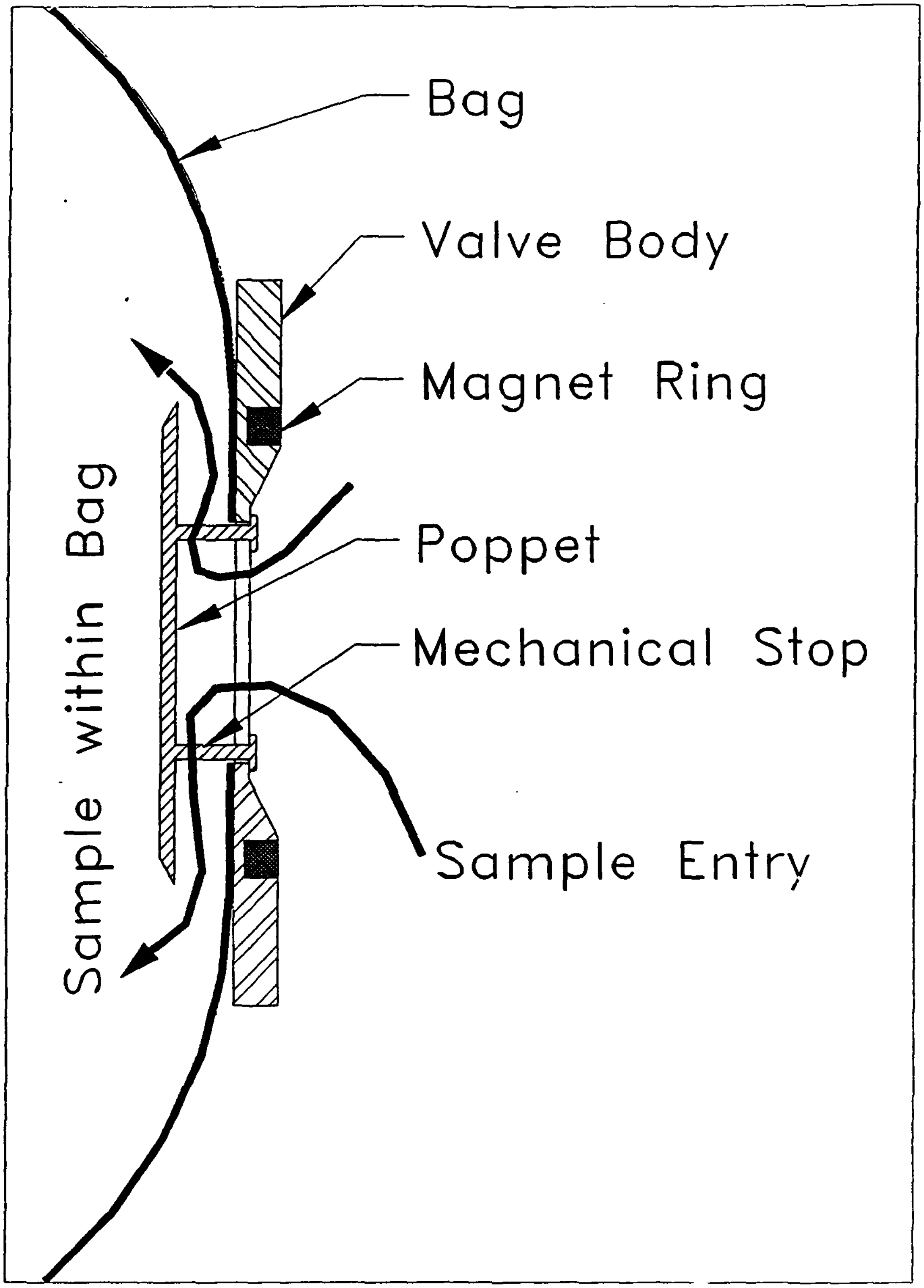


Figure 4: Inlet Poppet Valve Assembly

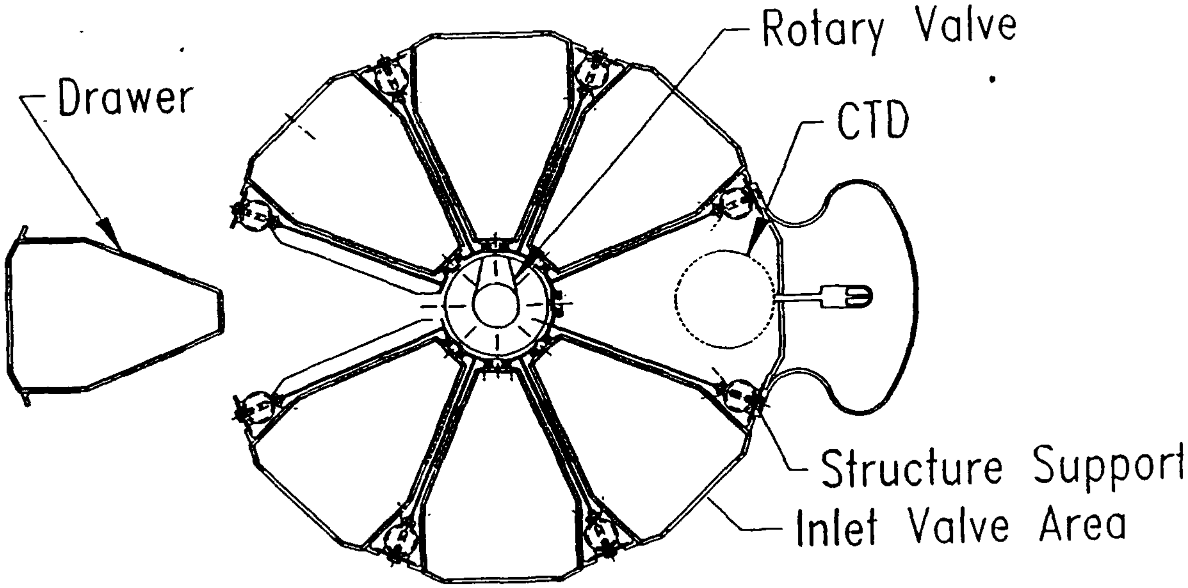


Figure 5: Cross-Sectional View of Water Sampler

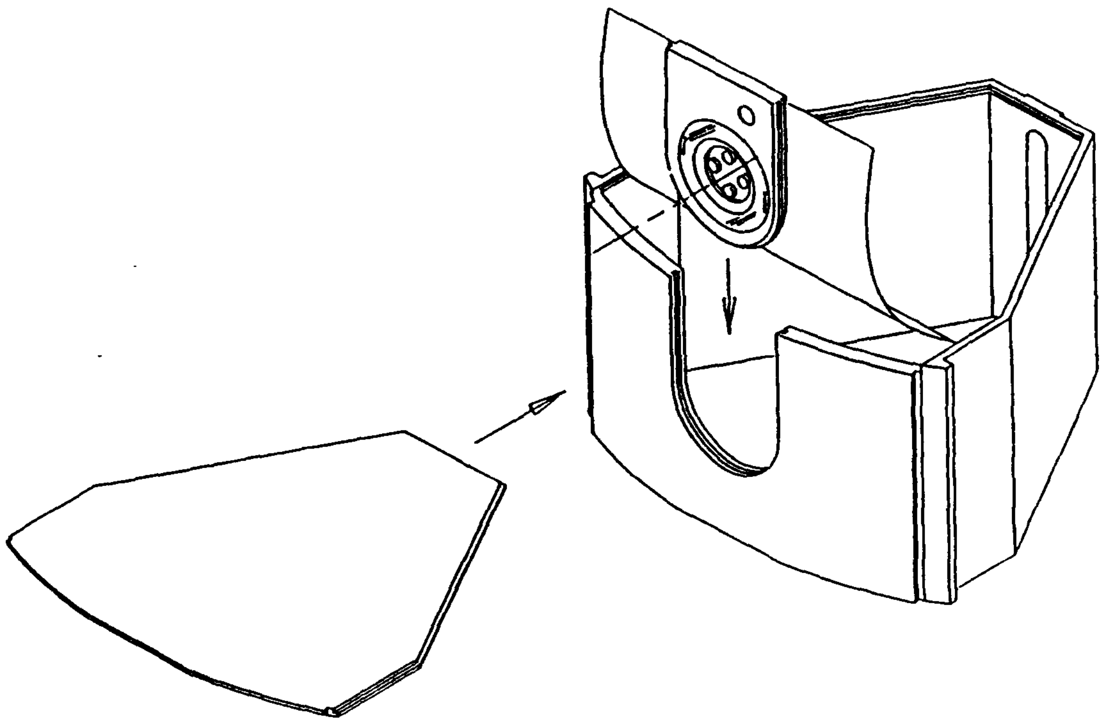


Figure 6: Drawer with Water Sample Container

Ports on the fixed tube are located on five levels, at 72° intervals, and provide the connection to the sample drawers. These ports mate with corresponding ports on the backs of the 36 sample drawers.

The rotor is located inside the fixed tube. As shown in Fig. 7, it consists of a cylinder with five branches, corresponding to the five levels of drawers within the seawater acquisition subsystem. The ports through the fixed tube to the drawers are separated at 45° intervals; the branches on the rotor are offset, separated on 72° intervals. This vernier provides the indexing action, allowing a unique port to be selected for each 9° step in rotor position. Four of the positions line up with the CTD compartments. Indexing of the rotor is achieved with a stepper motor. Positive indication of rotor position is accomplished with a rotary potentiometer and a home position limit switch.

A collar gear connects the bottom of the rotor to the flow meter, forming a flow path from the rotor to the inlet of the pump. The top end of the rotor is rigidly capped. Centering bearings are located near the top and bottom of the rotor, supporting the rotor in the fixed tube, independent of the rotary valve's mounting in the sampler. The annular space between the rotor and the fixed tube is free-flooding at all times.

The free-flooding annular space between the rotor and the fixed tube serves three functions. First, should a leak occur at the branch seals, the annular space prevents pump suction from influencing any samples other than the one being drawn. Second, this space provides the path for the sea to fill the drawers quickly during launch, and allows excess water to drain out on recovery. Third, this space provides the means for pressure compensation of sample containers.

The five branches of the rotor are provided with close-fitting delrin seals spring-loaded against the inside of the fixed tube. Only one branch is connected to a drawer, and water is drawn from that drawer. The four branches not aligned with ports are blocked by the inner surface of the fixed tube, thus preventing extraneous flow. In this way, only one possible flow path is permitted. Should leakage take place in any of the seals, the annular space is open to the sea and therefore, no other sample will be affected by the leak.

SAMPLE CONFIRMATION. Two instruments are used to confirm that a sample has been collected. The first is a rotary potentiometer that monitors the position of the rotary valve rotor, and can be interpreted to determine which drawer is connected to the suction of the pump. The second instrument is a flow meter, which verifies that water is being moved, and, by integrating over time, can be used to verify that the desired total volume has been collected. Since the rotor is indexed by a stepper motor, the encoder provides somewhat redundant feedback which is used solely to verify correct operation of the indexing mechanism.

The flow meter provides feedback on the progress of sample collection to the control computer. Because accurate control of sample volume is not necessary, there are no plans to use the flowmeter information to control the pump. Sample volume will be controlled entirely through timing. Rather like the rotary valve position encoder, the flow meter will be used solely to verify correct operation of the pumping system.

The flow meter will be placed on the suction side of the pump, between the pump inlet and the rotary valve. This location was chosen because turbulence should be less at the inlet, providing for less variability in the signal to the controller.

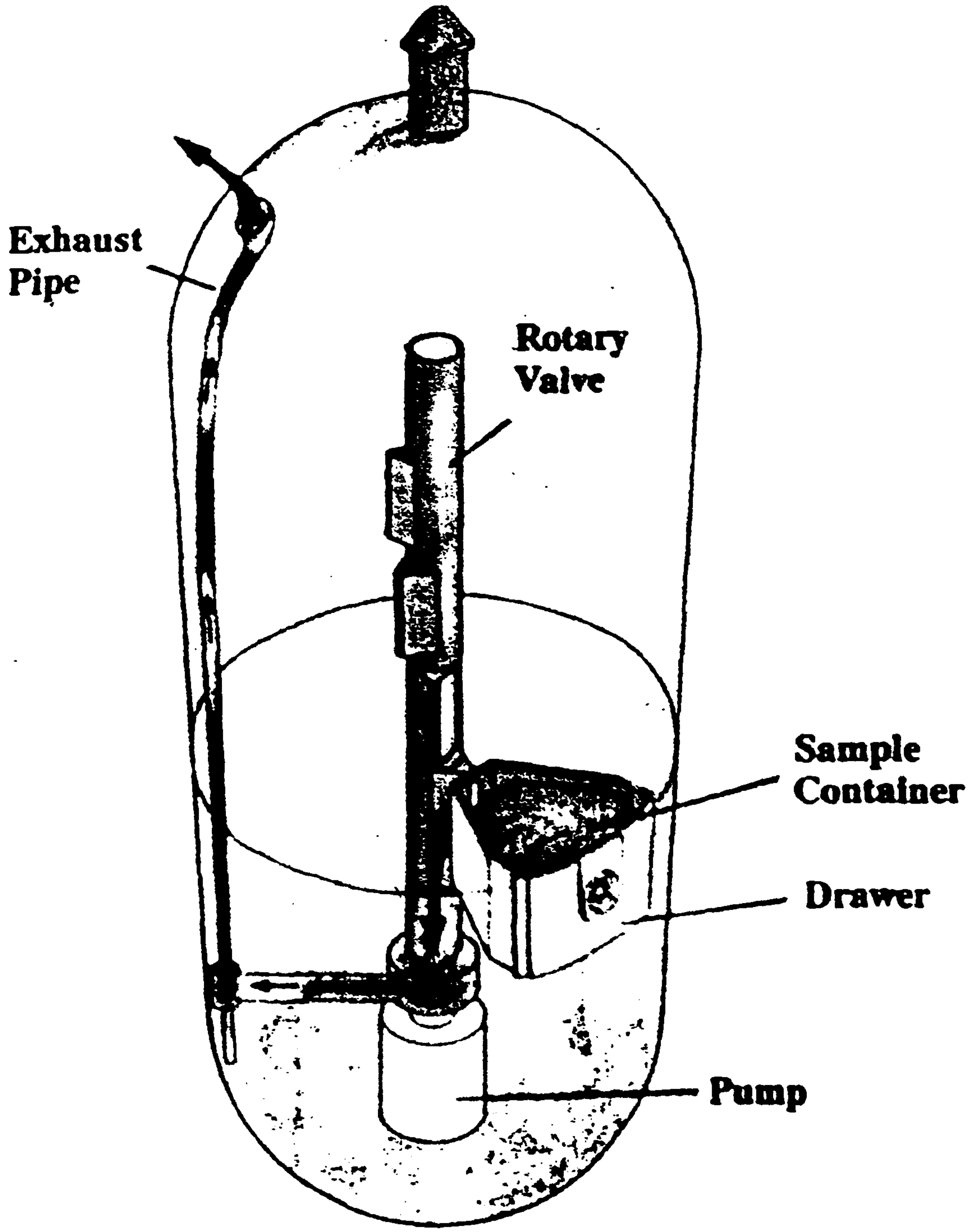


Figure 7: Rotary Valve Assembly

Due to space limitations, we needed a flow meter with a low profile, and because flow losses equate directly to increased energy consumption, we looked for a flow meter with low head losses. The flow meter should also have a simple input to the controller. The flow meter selected to meet these criteria is a turbine meter. This meter uses a simple turbine which is rotated by the flow of water over its vanes. A sensor in the periphery detects the rotation of the turbine magnetically, generating a pulsed signal to the controller.

PUMPING SYSTEM. To collect a sample, the pumping system is used to draw a suction on the selected sample drawer. The pumping system, shown in Fig. 8, consists of a centrifugal pump, a valve which selects whether the pump will discharge at the top or the bottom of the underwater unit, and the piping necessary to connect these to the rotary valve.

The pump is a simple centrifugal pump. All-plastic construction was selected for corrosion resistance and weight. Fasteners in the pump body and the shaft from the motor drive are stainless steel. The pump had to meet two flow conditions: high suction pressure at low flow (when developing the suction required to initially open the closure valve), and high flow against reasonably low head losses (to move seven liters in less than five seconds). A Sequence 1000 pump from Multi-Duti Manufacturing of Baldwin Park, CA, was found to meet this requirement. During Phase I a pump was purchased and tests were conducted to verify that this pump met or exceeded all of the requirements for the sampler.

The motor driving the pump during Phase I testing was a 560 Watt (3/4 horsepower) AC motor, provided by the pump manufacturer. For use within the underwater unit, the pump is driven by a 500 Watt, 48VDC motor. The motor, which was purchased from Lansea Systems Incorporated, is oil-filled, pressure compensated, and closed-coupled to the pump.

Because the seawater acquisition subsystem initially is flooded with surface water, care must be taken to assure that the water discharged from the pump is not allowed to enter through the closure valve and contaminate the sample with water carried to another depth by the unit. This is accomplished by directing the discharge of the pump so that it always comes out in the wake of the underwater unit. During sampling on the downcast, the pump will discharge on the top of the underwater unit; on the upcast, the pump will discharge on the bottom. In this way, the pump's discharge is always left behind the unit and cannot reach the inlet of the sample being collected.

The directional discharge valve is a three-way valve. In one position it directs discharge to the top (downcast) outlet. In the other position, it directs discharge to the bottom (upcast) outlet. The custom valve is coupled to a stepper motor. The position of the discharge valve is changed only two times per cast: once, at the beginning, to move discharge to the top for the downcast, and once, at the bottom, to shift the discharge to the bottom for the upcast.

Water Sample Transfer System

The water sampler's distinctive feature is the use of flexible water sampler containers. Because these sample containers can be removed from the underwater unit, they also serve as transport containers, thus eliminating the need to draw water samples from the underwater unit while it is out on deck and exposed to the elements.

Sample transfer can be viewed as a two-step process: on-deck removal of the water sample containers from the underwater unit, and laboratory extraction of the water sample from the sample container for analysis. Upon

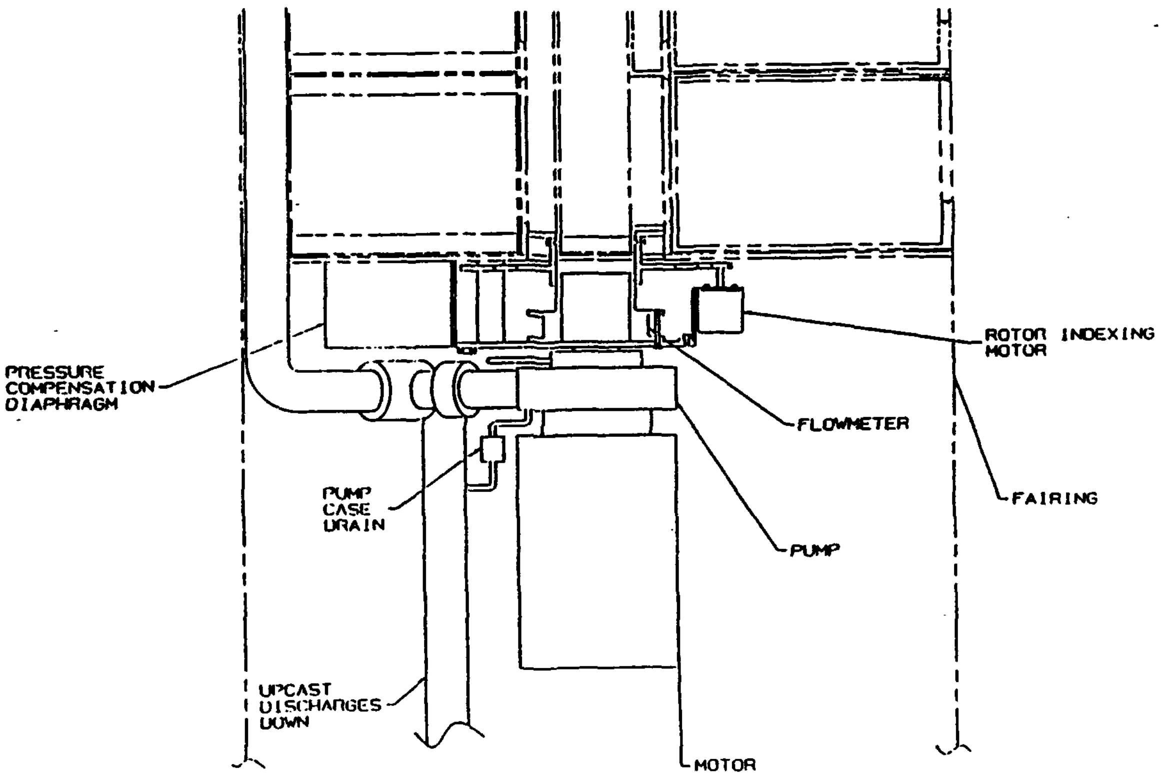


Figure 8: Water Acquisition Pumping System

recovery of the underwater unit, the drawers with full sample containers are removed from the underwater unit and transferred into the ship's laboratory. The drawer compartment acts as an insulated carrying case that will minimize warming and degassing of the water sample during transport into the ship's laboratory and during initial subsampling. The drawers weigh roughly 10 kg, including the seven liter water sample (7 kg).

Inside the ship's laboratory, water subsamples are drawn from the sample container. To draw the subsample, a transfer probe with flexible hose (Fig. 9) is inserted into the transfer port, puncturing the wall of the flexible container while sealing against the valve body. The water is free to flow through the probe/hose, and water samples are drawn for the various analyses. Due to the flexibility of the sample bag, water samples can be drawn without introducing any air or creating a gas headspace inside. To help with the extraction of the water, the flexible bag can be compressed to generate more flow. After all of the water samples have been removed from the sample container, the remaining water is drained. The valve body is removed from the bag material to be reused in the assembly of new sample containers, and the bag material is discarded.

CTD Data Acquisition Subsystem

The CTD data acquisition subsystem includes a standard CTD profiling package, battery power system, bottom-finding altimeter, and interfaces to the telemetry subsystem. This high resolution profiling system may be configured with additional sensors for the measurement of dissolved oxygen, pH, turbidity, fluorescence, and other chemical parameters.

Data Quality Requirements

Continuous profiles on both the downcasts and upcasts of temperature, conductivity, and dissolved oxygen, need to be made in addition to the taking discrete water samples without stopping the profiling operation. CTD/O_2 profiles will be continuous from the surface to within 10 meters of the bottom.

The WOCE requirements for CTD sensors and observations are given in the U.S. WOCE Implementation Plan, Implementation Report Number 1, (1989) as given below in Table 1.

CTD Hardware

The water sampler was designed to be compatible with the EG&G MK-III and MK-V CTDs and the Sea-Bird Model SBE-9 and SBE-11 CTD. Due to the widespread use of the EG&G MK-IIIB CTD, the sampler design team felt that it was imperative that the sampler be capable of supporting this instrument. Each of these instruments has unique advantages. A successful hydrographic instrument could be designed using either the MK-IIIB or the SBE-9, so neither was rejected. Both systems have established user groups within the community, so the water sampler was designed to adapt to both of them. There are also several other CTDs on the market, but it is not likely that any of these would be used during WOCE. However, the basic design does not preclude other CTD sensor systems. Representatives of both EG&G and Sea-Bird were present at the water sampler planning meetings and offered much useful advice. We are grateful for their input. The water sampling underwater unit can accommodate either of these systems mechanically and electrically.

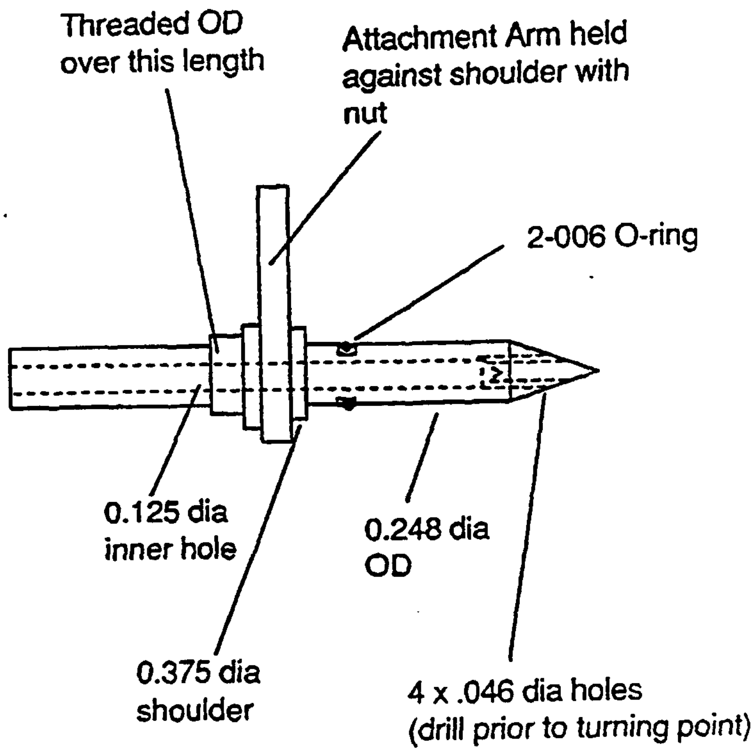


Figure 9: Water Sampler Extraction Probe

*Table 1: WOCE Requirements for CTD-Sensors**

Quantity	Accuracy	Precision
Temperature	0.002°C	0.0005°C
Salinity[1]	0.002 PSU	0.001 PSU
Pressure[2]	3 dbar	1 dbar
Dissolved Oxygen[3]	1 - 1.5%	1 - 1.5%

NOTES:

* Copied from Table II.A.3, page 26 in the U.S. WOCE Implementation Plan, U.W. WOCE Implementation Report Number 1, March 1989.

1. Although conductivity is measured, data analyses require knowledge of useful limitation expressed as salinity. The accuracy requirement depends on the frequency and technique of calibration, and the precision depends on the processing techniques.

2. Pressure accuracy depends on careful calibrations and precision limits depend on processing. Difficulties in CTD-salinity data processing occasionally attributed to conductivity sensor problems or shortcomings in processing actually are sometimes due to difficulties in accounting for pressure sensor limitations.

3. An adequate oxygen sensor does not exist.

ELECTRICAL INTEGRATION OF CTD SUBSYSTEM: Electrical integration of the CTD must insure that the highest quality CTD data be delivered to the surface in a manner not affected by its use with the water sampler. The data transfer needs from either CTD system far exceed the modest communication requirements of the water sampler. The CTD data rates are listed in Table 2.

The Data Command/CTD Data Telemetry System integrates data from various sources and insures a high reliability of data reaching the surface. The conceptual design allowed for the continued operation of the water sampler in the event of a CTD system failure. The system was designed to work on hydrographic cable that has poor electrical characteristics. The telemetry system allows for the use of standard off-the-shelf Sea-Bird (SBE-9 or SBE-11) or EG&G (MK-IIIB or MK-V) CTDs with the water sampler. We avoided the use of modified CTDs since this would have limited the number of CTDs which could be integrated with the sampler. Since CTDs must continue to function in their usual role, modification for use with the sampler could have resulted in other operational difficulties.

Table 2: CTD Data Rates

Manufacturer	Model	Data Rate (Bits/Sec)
EG&G	MK-IIIB	5,000
EG&G	MK-V *	9,600
SEA-BIRD	SBE-9	5,760
* NOTE: The EG&G MK-V CTD can be supplied with a 5,000 bps system.		

The telemetry system did not alter the users' normal computer interface to the CTD data, as the telemetry system's deck unit emulates the format and protocol of the manufacturer's standard data. The Neil Brown MK-IIIB, and the Sea-Bird SBE-9 CTD's both output data serially by FSK or Manchester encoding respectively. The telemetry system provides for demodulation of either Manchester or FSK encoded data. The CTD instrument specific demodulator will plug into the telemetry system to allow for transition from one CTD manufacturer type to another.

Table 2 gives the base data rates for the major CTD instruments in use as typically 5,000 bps. At this rate the instruments are producing a minimum of 24 scans of CTD and auxiliary sensor data per second (12 measurements meter). The Sea-Bird SBE-9 data frame consists of 24 bytes of data which are transmitted in 12 Manchester encoded words. Each Manchester encoded word contains two bytes of data and 4 data control bits. A "Modulo" word is used to synchronize the data receiver. The EG&G MK-IIIB CTD transmits up to 15 bytes of data for each scan of CTD dependent upon the number of auxiliary inputs the instrument has. Each frame of data is synchronized by an idle state which is more than 1 byte time. The EG&G MK-V CTD uses a system similar to the MK-IIIB unit. The major constraint in data telemetry is the bandwidth of operation for hydrographic cable. The measured attenuation figures of UNOLS standard hydrographic cable are given in Table 3.

Telemetry systems which have frequency components which exceed 15 kHz begin to exhibit significant amplitude attenuation problems. In addition to attenuation, other long cable effects may be equally destructive to data telemetry systems. Frequency dispersion, differential phase shifts, and other effects deteriorate the performance of FSK or Manchester signal demodulators. From this data we have selected a maximum up-link data telemetry rate for the telemetry system of 1200 baud. Using an F/2F system will result in a maximum telemetry frequency of 2.4 KHz.

POWER CONTROL CIRCUITRY: The power control module provides power from a DC to DC convertor and a linear constant current regulator to power the CTD instruments from the water sampler. The voltage and current requirements for the Sea-Bird and EG&G CTD systems are shown in Table 4.

For integration and testing, an EG&G MK-IIIB was borrowed from the WHOI CTD group.

Table 3: Attenuation of UNOLS Standard Cable Versus Frequency

FREQUENCY	ATTENUATION (dB)
1,000 Hz	-1.41
5,000 Hz	-12.04
10,000 Hz	-17.50
15,000 Hz	-23.97
20,000 Hz	-32.71

* 30,000 feet (10,000M) of 3 conductor + armor

Table 4: CTD Power Requirements

Manufacturer	Model	Voltage	Current	Power	Regulation
EG&G	MK-IIIB	22 VDC	.17 Amp	3.7 W	Current
EG&G	MK-V	38 VDC	.30 Amp	11.4 W	Voltage
SEA-BIRD LP	SBE-9	50 VDC	.35 Amp	17.5 W	Voltage
SEA-BIRD HP	SBE-9	100 VDC	.35 Amp	35 W	Voltage

CTD MOUNTING AND INTEGRATION WITH THE UNDERWATER UNIT: The main objectives of CTD mechanical integration to the water sampler are:

- Obtain CTD data quality which equals that obtained with CTD when used without the sampler
- Allow for use of both major commercially available profiling instruments
- Minimize the requirements for modification of CTDs for use with the sampler
- Achieve high quality CTD data during both down and upcasts of the sampler
- Minimize the possibility of sensor damage during deployment recovery operations
- Minimize the probability of damage in the event of bottom contact with the sampler

Achieving these objectives required a trade-off in design and performance. During the Phase 1 development meetings various approaches were explored. A brief history of the progression of these is given below to in rationalize the final design concept.

The initial design proposal placed the sensors several inches below the bottom of the package (to be outside the stagnation layer), where the ability to make undisturbed downcasts was optimized. However, during the upcast the sensors are entirely within the disturbed flow of the sampler, resulting in poor upcast data collection. In addition, this approach allows the sensors to be exposed to contact with the bottom and possible damage during launch/recovery operations.

The upcast problem can be addressed by placing sensors at both ends of the sampler. The sampler would electronically switch between the two units as a function of sampler direction. However, this assumes monotonic direction of the unit due to proper function of the motion compensator system, with no direction reversals in the sampler descent. It would also double the number of sensors which the instrument must carry, and result in problems of maintaining intercalibrations of the two sensor suits. Using an EG&G CTD would require the use of two instruments, thus doubling the CTD payload (and cost) and greatly increasing the overall size of the sampler.

A third approach, more consistent with the overall design of the water sampler, was to mount the CTD sensors internal to the sampler. The water to be measured would be pumped into the sampler and past the CTD sensors. The water sampling duct would be oriented to the direction of sampling. This approach solves many of the problems of CTD sensor protection; however, the quality of CTD data would be limited due to the effects of the ducting/pumping of the seawater to be measured. CTD data would be smeared by the entrapment of water in the boundary layer of the ducts. In addition, the thermal mass of the system would be large, and at the higher sampling rates (2 m/s) would result in a long relative time response of the system.

The next approach, which dramatically reduces CTD data disturbance and allows for high quality data during both the downcast and the upcast, was to mount the CTD sensors on an arm, which is orthogonal to the vertical center line of the sampler, and protrudes out into the free flow. In this design the sensors would be well outside the flow boundary layer of the sampler package for both the up and down cast. This approach obtains the highest quality CTD data, but leaves the CTD sensors exposed during launch and recovery operations. The sensor arm can easily become entangled in guidelines or other ship-mounted structures.

Because the "arm" approach yields the best possible CTD data, the design group worked to resolve the negative aspects of this concept. The sampler has a built-in controller to execute the process of water collection which could also be used to deploy and retrieve the CTD sensors after launch and prior to recovery. This approach would allow the sampler to obtain the highest quality CTD data and also would protect the vital CTD sensors from physical damage.

Two mechanical approaches to the CTD deployment arm were examined. The first, which minimizes sensor cable constraints, was an arm which hinged out from the circumference of the instrument, extending the sensors 10 inches from the side of the sampler. Although this reduced cabling problems, it was determined that inadequate space was available in the sampler. The second technique was to deploy the arm on a ram extending directly out from the side of the sampler. This method minimized the internal vertical space requirements and allowed for the use of a simple rack and pinon gear actuator. This arm also allowed the Sea-Bird sensors to be mounted internal to it, with water being pumped to them via a vane mounted at the end of the arm. The EG&G sensor would be mounted externally at the end of the arm. During the use of either instrument, the dissolved oxygen sensor would be mounted internal to the arm and have water pumped to it. This will reduce the velocity dependent characteristics of the membrane sensor by achieving a constant flow rate past the device.

The sampler design team felt that the deployment arm with CTD sensors achieves all of the objectives outlined relative to CTD integration with the sampler. (A detailed discussion of this design is given in the Phase II proposal, April 1989). However, none of the existing CTD systems could be used satisfactorily "as is" for this configuration. The EG&G MK-IIIB system required major modifications. The Sea-Bird system with remote sensors would quickly adapt to use with the sampler, but the lower static accuracy of the system would not meet overall WOCE CTD data collection requirements. The EG&G MK-V CTD, which was designed with the intention of being adapted to remote head applications, presented less of a problem. However, its use for this program was inappropriate as neither Battelle or WHOI own an MK-V. In any event, the EG&G MK-V CTD must establish its performance abilities in making base CTD measurements prior to its adaptation to this development program.

It was not appropriate to modify an exiting CTD or to obtain another a new unit, so to expedite testing, the existing WHOI EG&G MK-IIIB CTD was mounted in the water sampler (Fig. 1) so that the CTD's pressure case was within the underwater shroud near the lower end. The sensors extended out

into the flow 3.5 inches. This configuration was selected so that at the 2 m/s expected descent speeds the sensors were well outside the expected 2-inch thick boundary layer around the sampler. Thus the sensors were (theoretically) in undisturbed flow. A fixed sensor guard was placed around the sensors to prevent damage should the water sampler bump into the side of the ship during launch or recovery. The guard was placed so that it would not affect the flow past the CTD sensors. However, a potential problem with this configuration is that an uneven fall rate or unstable descent could affect the thickness of the boundary layer or create a flow stagnation which possibly could affect the CTD readings.

Bottom-Finding Altimeter

Prevention of bottom impacts by the water sampler is essential during profiling operations which extend to near-bottom regions. Conventional methods of shipboard measurement of water depth, and real-time monitoring of the wire out and CTD depth during descent are not adequate for rapid profiling near the bottom. Therefore, a bottom-finding altimeter was required to measure, and to send to the operator/scientist in real time, the distance of the water sampler from the bottom.

A Seascan, Inc. (North Falmouth, MA) 12 kHz bottom-finding altimeter was purchased and mounted on the underwater unit (see Appendix B). The altimeter was powered from the water sampler's 24 v battery pack, and was interfaced to the water sampler's on-board controller, using an open collector SAIL interface, to allow data regarding the distance above bottom to be telemetered to the shipboard deck control system for display. With proper software, this data could be used as an automatic warning system of bottom approach. When queried, the unit replies with *####.#*, the distance to the nearest target in meters. This assumes a 1,500 m/sec sound velocity, which should be adequate since any errors will go to zero with the range. The transmitted pulse width can be set from 10 to 20 ms, and the power can be set to any percent of the full power. The repetition rate can also be programmed for 1 to 99 seconds, with 8 seconds being the default. This matches with the maximum listening time for a return of 8 seconds, which gives a maximum range of 6,000 m, much greater than acoustic attenuation allows. Software control in any bottom alert software could change the repetition rate to optimize control as the bottom is approached. This should provide optimum computer control of the altimeter during profiling operations.

The altimeter subsystem was tested as part of the 16 April - 3 May 1990 cruise from WHOI to Bermuda and back. The automatic warning software control had not been developed, but manual control, return and display of data from the altimeter was successfully achieved over the water sampler's telemetry link. The altimeter was able to detect and follow the bottom from greater than 1500 m range. Some noise or jitter was detected in the altitude, which suggests that some software development, and optimum adjustment of the blanking will be necessary to unambiguously detect the bottom with this altimeter. For more detailed discussion of performance, see "Test and Evaluation Cruises" discussion and the Tables of Altimeter Results in Appendix C.

Control, Monitoring and Telemetry Subsystem

The control, monitoring, and telemetry subsystem receives sampling requests from the surface, and actuates sampling through the sampler control module. The electronic control package also interfaces to the CTD and altimeter, and transmits all information to the surface. The battery power pack provides power to the water sampler so that the lowering cable handles only CTD data transmission and water sampler communication.

System Requirements

SAMPLER OPERATION: The operation of the water sampler requires the transmission of commands to the underwater unit from the surface and the corresponding transmission from the underwater unit to the surface of status information, command confirmation, and autonomous sensor data, such as the altimeter. Additionally, the same cable transmits data from a CTD attached to the sampler to the surface.

The goal of the telemetry system was to enable operation of the sampler over the same electrical conductors in the electro-mechanical cable as those used by the CTD on a non-interfering basis, with no modification to whatever CTD or readout unit that was used. This was done by dividing the available bandwidth on the EM cable into bands, the CTD using 5 kHz and 10 kHz for its FSK operation, and the controller and other instruments using 1.2 kHz and 2.4 kHz for its frequencies.

The system was designed to allow a number of serial devices to be connected together and operated over the same wires using the SAIL loop protocol. In this manner the CTD is separated by frequency from all other devices and the various serial devices are separated from one another by addresses specified in the messages sent. These serial devices are interrogated and commanded at 1200 baud and remain addressed until cleared from the shipboard operator's console.

In addition the controller electronics and CTD originally were to be powered by the sea cable with the control and data signals superimposed on top of the dc power. However, the power required to drive the pump, directional valve, and positioning motor were too great to be carried by the cable, so it was supplied by battery packs mounted in the water sampler frame.

The telemeter system functions by inserting an electronics unit top and bottom between the CTD and its readout which combines the serial data or commands from the water sampler controller with the CTD data, sends the combination up the wire, and then splits them apart at the surface to go to either the water sampler operator's terminal or the CTD readout.

The sampler is controlled by serial commands sent down the cable at 1200 baud. Each device (the controller and the altimeter in the tested case) attached to the SAIL loop is addressed by a unique header address, and then that particular device, and only that device, responds to any commands until it is released by addressing another device. The sampler responds to a number of two-letter commands to do such things as move to drawer n, pump for n seconds, change the directional valve to downward exhaust, etc. (This is discussed more fully below).

CTD DATA PASSTHROUGH: No changes were made to the hardware or software of the CTD and its readout unit. The only requirement was that the CTD have the appropriate options to take as many analog data channels as were needed, a standard configuration. The sampler frequency channels were separated far enough from the CTD's channels that they were transparent and did not cause any degradation in the signal-to-noise ratio.

OPERATOR'S CONSOLE: On board ship the sampler was controlled using an Epson Equity I+ personal computer with the CTD/Controller separation electronics built on a card plugged into the computer's backplane. Commands could be given to the controller or the altimeter from the keyboard, and the status and confirmations displayed on the screen. Two modes of operation were provided for. An operator's program, written in QuickBasic, provided a schematic screen with status information shown and menu selections. This was for normal operation. A commercial terminal program that was also used

allowed engineering personnel to execute a superset of instructions and to gather much more engineering data on sampler performance than the normal operator's program allowed, in addition to performing the standard operations.

Telemetry

THEORY OF OPERATION: Development of a command/response telemetry system allows for 1200 baud full duplex data communication to operate in unison with standard CTD profilers. The telemetry system uses advanced Digital Signal Processing modems. These modems employ digital equalization and demodulation techniques, enabling the additional communication channel to operate via frequency subdivision techniques. The telemetry system also allows for communication with auxiliary instruments, such as an altimeter, used in conjunction with the sampler.

The sampler requires an operator to communicate with the underwater unit to select chambers, set exhaust direction and to set sample size (1 to 7 liters). The operator may also request engineering status data to monitor sampler performance and to ensure correct operation of the device. Communication over the EM cable, therefore, must be bidirectional, allowing for downward transmission of control "commands" and upward transmission of conformation responses or "status" data.

Commercially available CTD systems use either Frequency Shift Keyed (FSK) or Manchester encoded data telemetry schemes to transmit data via the EM cable to a surface receiving unit. Although EM cables often have multiple conductors, their use as individual communication channels is not feasible due to the stray capacitance between the conductors. This capacitance results in CTD data signals (with their higher frequency components) being superimposed on all conductors after travel over 10-kilometer long EM cables. In addition, the use of individual conductors to transmit different signals reduces overall system reliability because individual conductor failures are frequent in EM cables. Therefore we needed to develop a telemetry system which would 1) work with standard commercially available CTD systems, 2) provide a bidirectional full or half duplex command channel to control the sampler, 3) work over 10-kilometer single conductor EM cable, and 4) support standard baud rates and data transfer protocol.

The command/status telemetry system developed is block diagramed in Fig. 10. The system is connected between the CTD underwater unit and its corresponding deck unit. The operation of the CTD system is not affected by the use of the sampler command/status communication system. This is achieved by the use of frequency subdivision techniques of the available bandwidth on the EM cable. Its response is flat with a small 2 dB peak at 3 kHz, and then drops of rapidly after 20 kHz. For the CTD, as shown in Fig. 11, the significant energy bands are centered on the two telemetry frequencies of 5 kHz and 10 kHz. However, there is significant energy across the entire sea cable bandwidth radiated from the instrument. From Fig. 11 it is evident that little bandwidth remains available to add the command status channel above the MK-IIIB CTD Data signal. Therefore, the command/status communication uses transmission frequencies below the lower CTD carrier frequency.

The command status telemetry system uses a Di-Bit Phase Shift Key (DPSK) data encoding technique. The use of DPSK allows the telemetry system to operate with low frequency carriers of 1.2 and 2.4 kHz while achieving full duplex 1200 baud operation. The Di-Bit phase shift representations of the

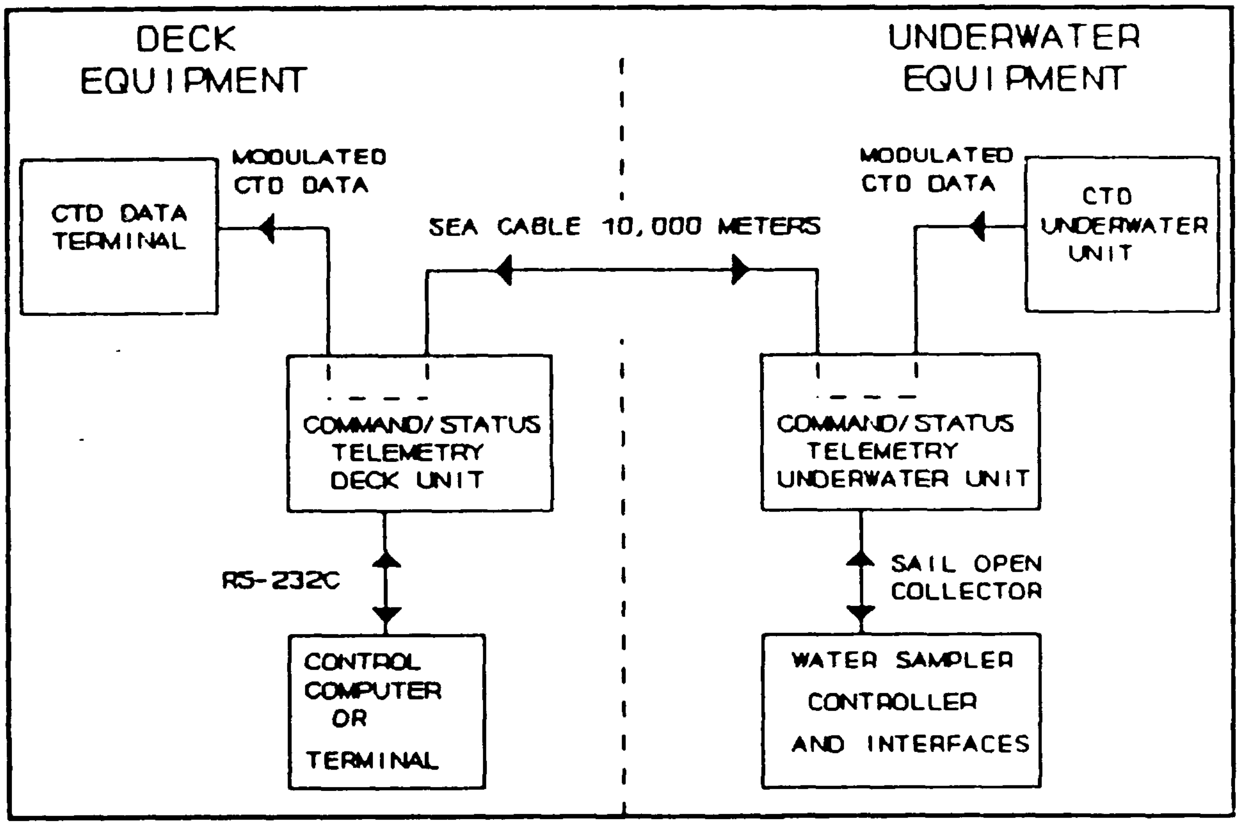


Figure 10: Block Diagram of the Command/Status Telemetry System

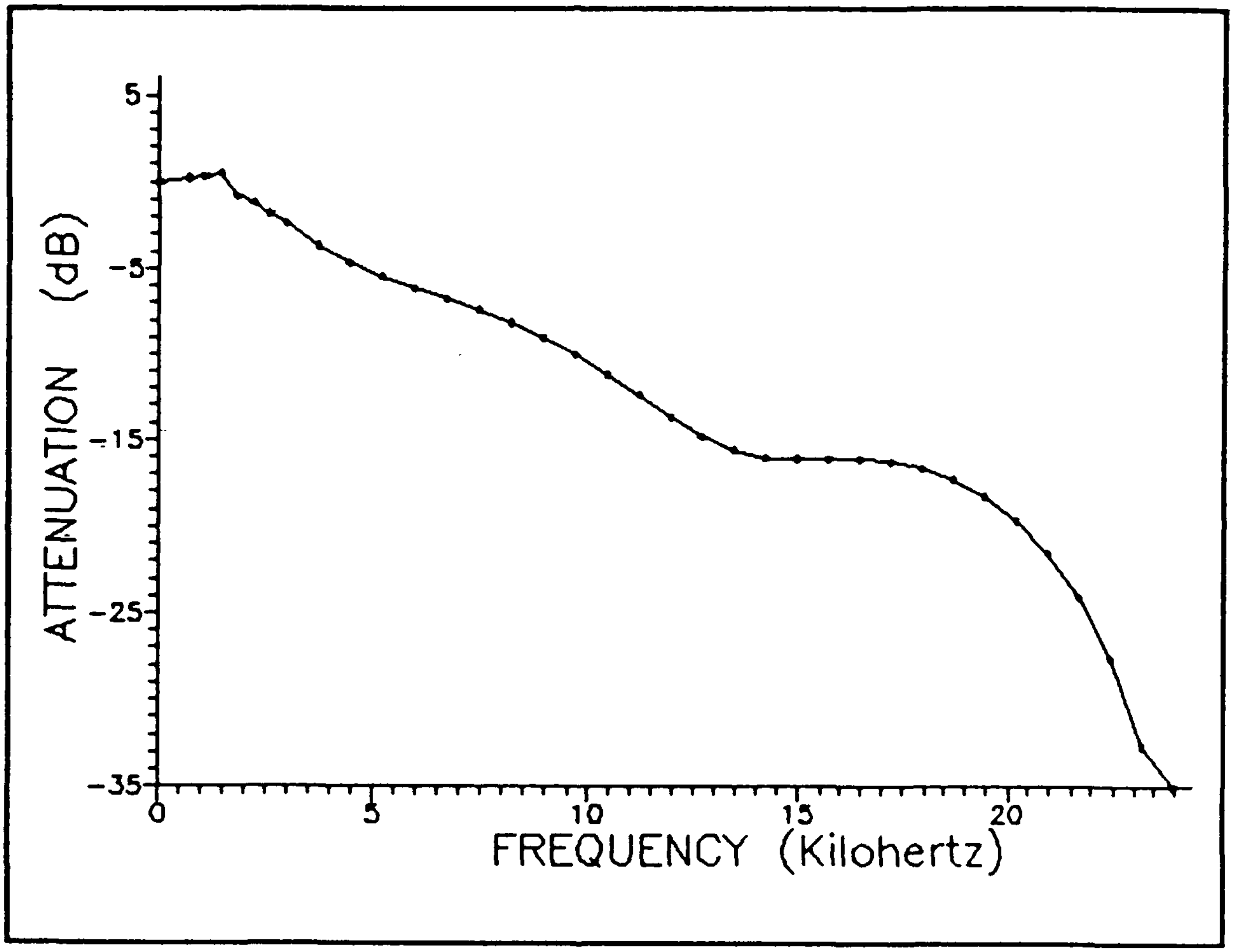


Figure 11: Spectra Showing Energy Bands of CTD Signal

carrier signal are listed in Table 5. Each of the four relative phase shifts represents two data bits. The carrier is phase modulated at a rate of 600 times per second resulting in a data transfer rate of 1200 bits per second. The DPSK modulator base-band signal output is then filtered to reduce intersymbol interference. Demodulation is the reverse of the modulation process, with the incoming analog signal eventually decoded into Di-Bits and converted back into a serial bit stream. The demodulator also recovers the data clock which was encoded into the signal during modulation. The command/status modem uses a phase locked loop coherent demodulation technique that allows for better performance than do other types of di-bit demodulators.

The command/status modem is susceptible to interference from signal frequencies transmitted by the CTD. Commercially available CTD systems radiate energy outside of their FSK bands which is a result of internal digital circuitry, DC/DC convertors, and signal switching internal to the instrument. These noise sources must be eliminated to allow the command/status modem to operate in an acceptable signal to noise environment. CTD designers also intended their underwater units and deck terminals to be connected directly together providing AC grounding appropriate to signaling frequencies used. At lower frequencies these networks do not provide sufficient AC grounding. Another requirement of CTD operation is that they receive their operating power by DC current supplied on the same conductors as the data telemetry.

UNDERWATER UNIT: The underwater unit intercepts the CTD data on the EM cable, and removes it. The CTD signal is then processed to remove interfering frequency components, the command/status data is added to it, and the resultant signal is re-modulated back onto the EM cable. A block diagram of the underwater unit is shown in Fig. 12. The system passes the EM cable through a PI filter, which essentially acts as an AC signal short. The PI filter also allows the command/status underwater unit to power itself via a tap taken from the center of the PI filter consuming about 750mw. The combined CTD and command/status output signal is amplified and driven onto the sea cable by a Programmable Gain Amplifier (PGA).

A series resistance "Rs" in series with the PGA enables transformer T2 to act as both a transmitter and receiver as it is driven from a high impedance source. Winding W2 of T2 receives both the "command" signal transmitted from the surface and also the "echo" of the CTD data and "status" data transmitted from the underwater unit. The magnitude of the receive signal "Vr" across winding W2 is directly proportional to the turns ratio "N" of the transformer, series resistor "Rs", and the resistance of the sea cable "Rc". The relationship is given by the equation:

$$Vr = Vi * N^2 * Rc \, / \, (N^2 Rc + Rs)$$

where Vi = input signal from the PGA amplifier.

In the command/status underwater unit receiver a difference circuit enables rejection of the locally transmitted portion of the signal. To insure that the echo suppression circuit is operating properly and that received signals are within the linear range of the Digital Signal Processor Band Bass Filter (DSP BPF), an Automatic Gain Control (AGC) circuit is used. The AGC circuit detects the level of the "locally" transmitted signal as it is reflected in the winding W2 of transformer T2, and maintains this magnitude at a constant level. This insures that both the CTD signal and the command/status signal are optimally echo-suppressed by the difference circuit. Measured echo suppression was found to be consistently in excess of 30 dB for 0, 5 and 10 kilometer length cables.

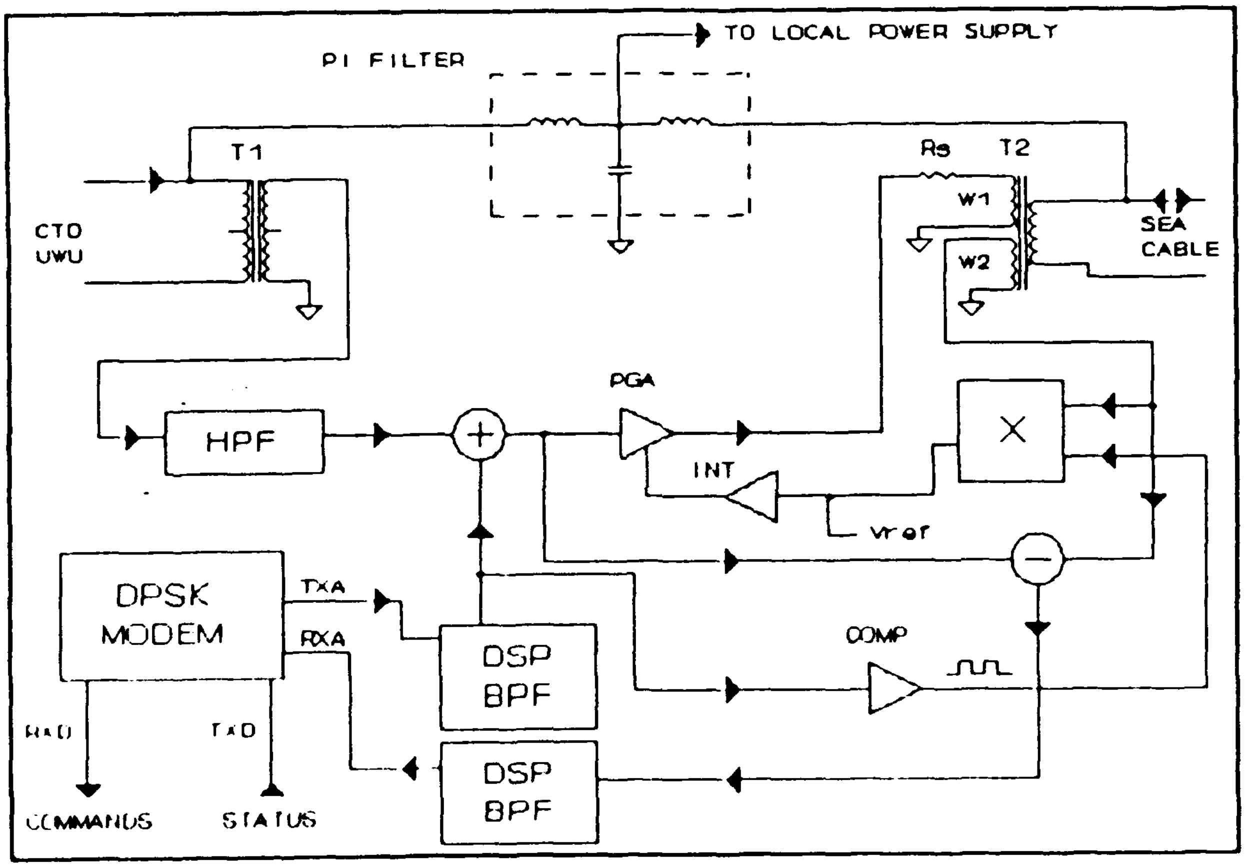


Figure 12: Block Diagram of Underwater Unit

Table 5: Di-Bit Phase Representation

DI-BIT VALUES	PHASE CHANGE (DEGREE)
00	+ 90
01	0
11	270
10	180

DECK UNIT: The deck unit is similar in operation to the underwater unit. A block diagram of the deck unit is shown in Fig. 13. The major difference in the deck unit is the use of high pass filtering in the CTD signal path to prevent the effects of the locally transmitted "command" signal from interfering with the CTD deck terminal demodulation process. The unit also uses an AGC loop to control the level of the locally transmitted signal. The deck unit is configured on a IBM/PC card format which can be mounted in an option slot of any computer. The deck card is powered from the backplane and communicates via a DB 9-Pin serial connector at the rear of the computer.

SEA CABLE COUPLING CARDS: All telemetry signals pass thru and are signal conditioned to some extent in the sampler modem card. Telemetry leaving the underwater unit (via the sea cable coupling card) include both CTD and Sampler data. The CTD's 5/10 kHz FSK data is first low pass filtered and then analog mixed with the Sampler's 1200 Hz DPSK data. The signal ratio is fixed at approximately 8:1 to accommodate for the large loss of the higher frequency CTD signal in the EM cable. This composite signal is then transformer coupled onto the EM cable by the sea cable coupling card. Commands from the Sampler deck unit are received at the underwater unit as 2400 Hz DPSK signals. They are transformer coupled to the sampler modem card via the sea cable coupling card. An echo cancelling scheme in which the outbound and inbound signals is used to eliminate the bulk of the unwanted signals at the receiver. A series of analog filters and a switch capacitor modem filter are used to further remove any out-of-band signals that may be present.

Sampler Control

THEORY OF OPERATION: It was not practical to control the sampler's performance from the surface, with passive controls in the sampler. That would have required many more conductors than were available. Furthermore, it seemed risky to place the 5000 meter length of electromechanical cable, its terminations, and the bottom and topside interface electronics inside the control loop. Therefore, an embedded controller was used so that the sampler could carry out complex tasks with only minimal intervention from the operator's location in terms of discrete commands. The sampler could then be programmed with "intelligence" to allow it to make some control decisions on its own and to establish end limits to prevent "runaway" if communication to the surface was lost.

CPU CARD: The CPU and A/D cards were a set of two marketed by Star Engineering Company. The CPU card is built around an Intel 80C52AH microcontroller preprogrammed in its ROM with a BASIC interpreter. The program embedded was the MCS BASIC-52, a reasonably sophisticated version of BASIC with provisions for assembly language routines and a variety of powerful programming utilities. This was coupled with CDM62256, 32k x 8 SRAM for

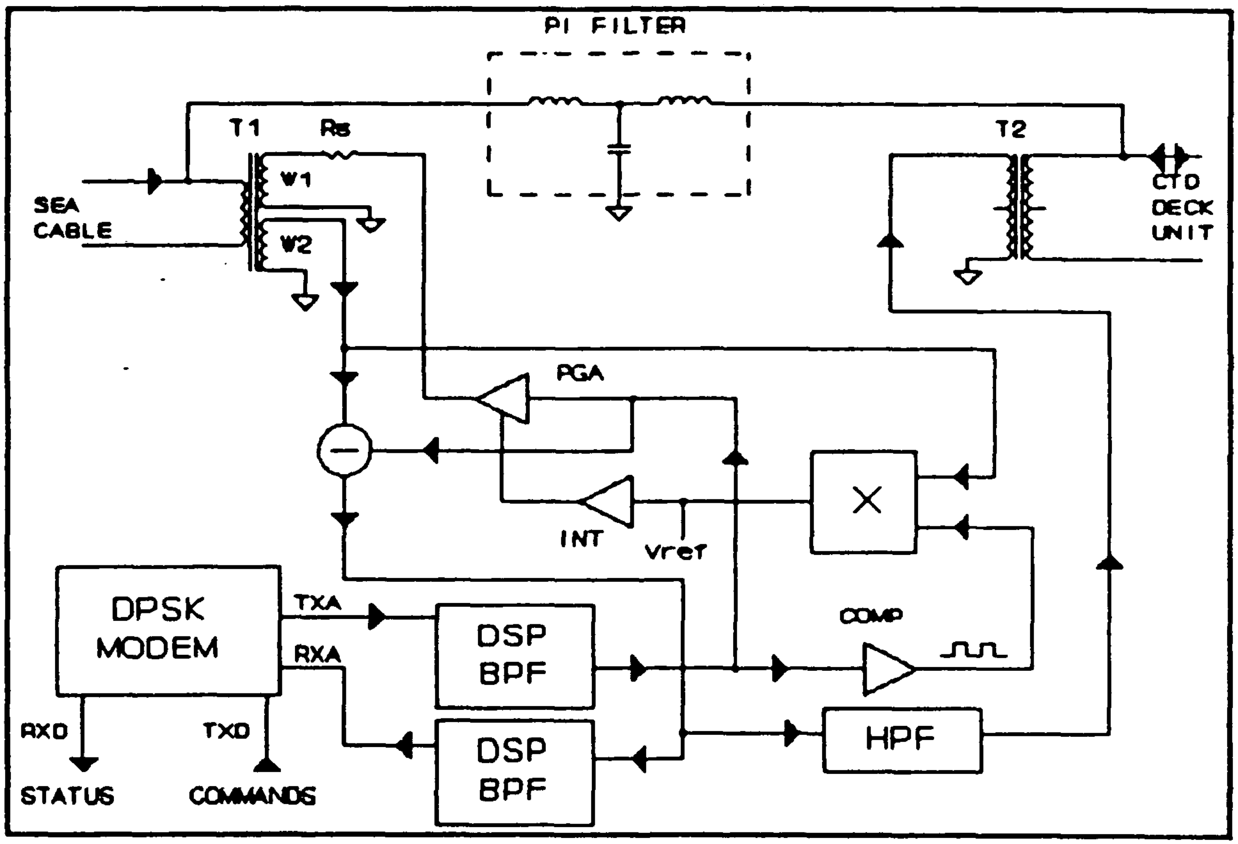


Figure 13: Block Diagram of Deck Unit

temporary storage and program development, a NMC27C256 32k x 8 EPROM for program storage, and an 82C55 Programable Parallel Interface chip providing three parallel 8 bit input/output ports to control external functions or sense conditions. These chips along with an RS232 serial communications driver chip make up the heart of the controller system.

A/D CARD: The analog to digital (A/D) converter card contains a TSC800 15 bit plus sign, dual slope, integrating, A/D converter; a precision reference voltage for the A/D converter; an 82C54 triple counter/timer with reference oscillator; another 82C55 parallel port; and some local regulators and power switches. The basic function of this card is to digitize the analog voltages to be measured (i.e., pressure sensor, rotary valve position sensor, battery voltage, sea cable voltage) and interface to the microprocessor. The additional parallel port chip extends the control capability further, and the counter/ timer chip determines the rate of flow through the flow meter sensor on the exhaust manifold.

AUXILIARY CARD: The auxiliary card is a catchall for the various pieces of interfacing logic, regulators, power converters, and special circuits needed to interface between the controller and the system operators and sensors. A number of opto-isolators are used to isolate the battery operated circuits and the sea cable powered circuits. The multiplexer for the A/D converter is on this card, as are numerous power control switches (FETs) to disable the high voltage power (and current drain) when not required. The circuitry to prevent the altimeter SAIL echoback from disturbing the controller is also located here. Latches hold the input signals to the stepper motor controllers so that the processor could be doing other tasks while steppers rotate and the directional valve and rotary valve position themselves.

POWER SUPPLY CARD: This card, as its name implies, provides the conversion of the power coming down the sea cable from 30vdc to the various voltages needed by logic, operational amplifiers, the CTD/sampler seperator circuitry, and sensors. A low frequency filter removes the FSK communications signals from the sea cable voltage, and a number of DC/DC converters efficiently transform the voltage to levels usable by the circuitry.

STEPPER MOTOR DRIVERS: Two stepper motor drivers were sandwiched between the electronics chassis and the pump controller, providing the drive and control to the directional valve and the rotary valve. Intelligent Motion Systems Models IB104 and IB1010 supply 4 and 10 amp currents to the stepper windings. Each driver has inputs from the processor to enable it, change direction, take half-sized steps, and the step input itself, driven by a pulse train that determines the step rate. Once the pulse train on the step input stops, movement stops, but the current in the windings stay on. The enable input allows the driver's output current to be turned off to save energy and prevent overheating.

PUMP CONTROLLER: LandSea Systems built the pump controller. It is a basic unit for driving a brushless dc motor with feedback from sensing devices in the stator to indicate rotation and determine the time to change the phase sequence of the applied power. A commercial chip set was the basis of the controller, with a high-powered output stage to drive the pump motor. It supplies up to 50 amp phase currents during start up which drops down to 10 to 15 amps at speed. Probably the biggest challenges in building the controller were minimizing its size, removing the built-up heat from the components, and driving the motor through relatively long wires without inducing excessive noise in the high impedance feedback lines.

Engineering Module

The engineering module's function is to monitor the physical movements of the sampler in pitch, roll, yaw, and the tension on its lowering cable. The analog output of these sensors is digitized by the CTD and transmitted to the surface along with the CTD's other data. The sensor suite consists of two Schaevitz Model AccuStar inclinometers for pitch and roll, a KVH Model LP101-WH fluxgate compass for heading, and a Metrox Model TC101 load cell to measure cable tension.

FLUXGATE COMPASS: The fluxgate compass was mounted on the side of the pressure case so that that it would be horizontal when the pressure case was laying horizontal in the bottom of the sampler frame. It has a gimballed sensor coil which allows accurate azimuth readings to be made for pitch and roll angles of up to 20 degrees.

INCLINOMETERS: The AccuStar inclinometer is a device with no moving parts. It functions by varying its capacitance as it is tipped from vertical. It is a ratiometric device with its output being one half the supply voltage at vertical. It has a useful linear range from 0 to +/- 45 degrees and is monotonic to +/- 60 degrees with a linearity of +/- 1 percent. The sampler's scaling was set up to produce an output of +/- 0.233v / degree or a full scale output(+/-10v) of +/- 45 degrees.

TENSION CELL: The Metrox tension/compression cell has a full scale range of 5000 lbs. It is actually a compression cell with a central hole through which a bar with tension on it could hang and effectively "squeeze" the compression cell. This cell is 4.5 inches in diameter and 1.32 inches thick, and is suitable for use at [illegible]00 meters depth. It has a scale factor of 2.031 mv/v full scale, amplified by a gain of 25 to give a 5.0v full scale readout to the CTD.

ELECTRONICS CARD: The electronics card in the engineering module contains the amplifiers and scaling networks that boost the sensor signal levels, various local regulators and dc/dc converters, and the auxiliary circuits needed for the fluxgate compass. Included as part of the compass circuitry is a 2.900 khz oscillator which serves as the AC reference input to the compass primary coil. Additional circuitry synchronously integrates the compass output to produce a 0 to $\pm$5 VDC output signal proportional to compass heading.

Battery Packs

The battery power pack provides power to the water sampler so that the lowering cable handles only CTD data transmission and water sampler communication.

DESCRIPTION: Two battery packs are used on the water sampler, each 7.5 inches in diameter and 18 inches long. They are basically both the same. The second has an additional connector to allow the the first to be connected through it to the controller since the controller end cap did not have enough room for a second power connector. It seemed advisable to have only one cable to remove to disconnect power to the unit.

Each pack is made up of two parallel strings of 24 each Gates 2.0 volt, 2.5 amp-hour, "D" size, sealed lead acid cells, making a battery assembly of 48 volts at 5.0 amp-hours. Each of the two parallel strings is diode protected to prevent interchange of energy between strings in case one string discharges faster than the other. The input connection for charging the pack was also diode protected to prevent charging from the wrong polarity. Connecting both packs together in parallel produced a capability of 10.0 amp hours.

The peak current output from the battery occurs when the pump motor is started and draws peaks of 40 amps for the 0.5 second it needs to get up to speed. When running, the pump draws around 10 amps for the three to four seconds necessary to fill the sample bag.

BATTERY CHARGING PROCEDURE: Each battery has two plugged purge holes which, with the watertight plugs removed, allow passage of 2-3 psi air from a pump to enter one hole and exit the other, purging the pressure case of explosive gases generated during charging.

Charging is done from a current limited supply set at 58 vdc at no load and limited to 2 amps charging current. As the battery pack charges, the current tapers off until the current is about 0.02 amps at full charge. A discharged pack should charge in three to four hours.

Rotary Valve and Pump Assembly

DIRECTIONAL VALVE: The directional valve diverts the water exhausted by the pump from behind the sample bag in the drawer to an area outside the sampler. As this is water that was trapped inside the back of the drawer at some other depth, it cannot be allowed to contaminate the samples being taken. Therefore a directional valve switches to exhaust the water upwards as the sampler descends, or downward as the sampler rises. This valve is powered by a stepper motor which rotates 180 degrees from one position to the other. Initially this motor was toggled back and forth, but it was determined it was too easy to end up in the wrong direction. Therefore separate up and down commands were used to make the stepper go clockwise and counterclockwise. Limit switches indicate when the valve is in each position. Directions change only when the pump is not running; water flow tends to impede proper positioning.

The directional valve was powered by an Intelligent Motion Systems Model HM200-3424-170A8 stepper motor, and driven by a Model IB104 stepper motor driver, the combination producing 156 oz-in of holding torque with 4 amp phase currents. At 1.8 degrees per step, it requires 100 steps to rotate from one position to the other, but slightly more steps were provided. The limit switches stop the motion.

POSITIONER: The sampler rotary valve is turned by a stepper motor connected through a ribbed belt. Movement to the next drawer is accomplished by stepping through the calculated number of steps. There are no restrictions as to which drawer can be next. The processor simply calculates the number of steps required between the two positions, always turning in the same direction. On any given tier of drawers, the angle between adjacent drawers is 45 degrees and requires 125 steps (note that all possible positions do not contain drawers). Each tier is offset from its neighbor by 72 degrees. Combining the five tiers, there is a new drawer position every 9 degrees; all the drawers could be filled by indexing 9 degrees every time a new drawer was selected. This would minimize positioning time and conserve battery power. However, it would result in a very awkward sequence of drawer numbers to keep track off, and it would not give the operator complete freedom to choose any drawer in any sequence, as is now possible. Any drawer may follow any drawer; the processor figures out the correct number of steps to accomplish this.

The stepper motor used to rotate the valve is an Intelligent Motion Systems Model HM-200-3450-700-A8 driven by a Model IB1010 stepper motor driver, producing a holding torque of 470 oz-in when driven by phase currents of 10 amps. It has a 1.8 degree step, followed by a 5:1 reduction in the sprockets and drive belt, giving a 0.36 degree/step output to the rotary valve. The stepping rate is a compromise between stepping slowly enough to not

misstep when trying to accelerate from standstill and yet fast enough so that the positioning time is not excessive.

POSITION SENSOR: The initial trials of the water sampler positioning system were done "open loop" with no positional feedback. The number of steps to rotate the central valve from the present drawer to the newly selected one was calculated, and the stepper motor given that number of steps to get to the new position. The number was calculated to give the minimum number of steps (hence the shortest positioning time) by indexing either clockwise or counterclockwise. When this was tried, it was found there was too much backlash in the drive belt and accurate positioning could not be accomplished. A switch to only clockwise rotation made the situation better but not good. It appeared that as the valve rotated the friction changed and the stepper would not turn the same number of degrees for an equal number of steps at various locations around the sampler. Adding or subtracting a number of steps to the number calculated could not make a good enough compromise in eliminating the positioning error. This indicated a need for some positional feedback.

Time was short, and a reasonable absolute optical encoder was not available, so a precision potentiometer with 360 degree rotation was fitted into a small pressure case and attached to the sampler frame while the shaft was brought out through a seal and coupled to the rotary valve shaft. The ends of the potentiometer were connected to common and full scale voltage, and as the valve turned, the voltage on the wiper would be proportional to its position. The controller would then compare the voltage on the wiper to the voltage calculated for the desired new position and determine the number of steps necessary to bring it to that position. The stepper was then instructed to go two thirds of the way to the target position and then to resample, recalculate, and again go two thirds of the way. This continued until the potentiometer indicated it was within 5 degrees of the desired position and then it was told to go all the way, there being not much of a chance for errors in this small amount of movement. This scenario produced very acceptable results, being not more than one sixteenth of an inch in error in aligning the slot in the valve and the slot in the sample drawer. The electrical dead spot on the potentiometer was positioned in an area where positioning was not required (no drawer slot existed). The potentiometer was fitted into a small pressure case and attached to the sampler frame while the shaft was brought out through a seal and loosely coupled to the rotary valve shaft.

Shipboard Control

CONTROLLER SOFTWARE: This includes the two communication paths going up and down the lowering cable, the CTD data and sample commands, and also the communication between devices hanging on the IEEE Serial Instrumentation Loop (SAIL). Each SAIL device has its own address to which it and only it responds. Below is a list of those devices in the water sampler system:

ADDRESS	DEVICE
#WS	Water Sampler Controller
#TM	Telemetry Module (Underwater Unit)
#TD	Telemetry Module (Deck Unit)
#AT	Altimeter

The water sampler controller, once addressed, awaits commands to take a sample on a prescribed drawer. The altimeter will respond with ranges and can also be directed to change its operating parameters, such as pulse length, power level, blanking time, etc. (see Appendix B). Likewise, the telemetry units may be directed to change their parameters for gain, filtering, and baud rate.

All devices, including any device already active, wake up when sent a # symbol as an attention character and then prepare to decode and check the next two symbols to see if it is their address. Once a device recognizes its address, it goes "active" and is ready to receive further commands, while the other devices on the line immediately become inactive. Depending on the particular device's software, the active device may complete its last command before returning to its command interpreter where it can recognize the # symbol. All devices also respond to a BREAK command (sending a "1" for one second) by becoming inactive. Once activated, each device will respond with a "CR"(carriage return - hex OD), a "LF"(line feed - hex OA), and an "ETX"(end of transmission - hex 03) to signify it has recognized its address.

Following is a listing of commands and responses for the water sampler controller and altimeter. Commands for the telemetry unit can seriously influence the operation of the system and should be executed only by a knowledgeable person. Therefore, they are not listed along with this general operator's type information.

In addition, each device has its own unique software for performing individual functions as specified by the commands. In the case of the water sampler controller, it receives other inputs in the form of feedback from various position and flow sensors which allow it to "home in" on an end point to the control action in a "smart" fashion. To perform the function "take a 3 liter sample in drawer 7" requires the completion of several commands interacting with the sensors. All commands are self completing and require no further communication with the surface, nor can they be influenced by surface control. Default limits are set which prevent "runaway" or attempts to perform unrealistic tasks.

The implementation of the Basic command set in the controller provides for stopping the program operation by sending an "ETX" (hex 03) character to the controller. However, the SAIL protocol uses this character as an acknowledgment, so addressing the altimeter would result in its responding with "CR" "LF" "ETX", shutting off the water sampler controller. Therefore, additional commands were written to enable and disable this function in the controller so that it could be stopped on command by reenabling it, but so that it would not respond to "ETX" when disabled as in normal operation.

For engineering purposes, other commands with different responses to the surface were provided to accomplish the same commands as shown above in the chart, while also sending a greater amount of performance data on data such as "homing" speed and accuracy.

OPERATOR'S CONSOLE SOFTWARE: A QuickBasic program was developed for use at the operator's console. It provided a schematic display of water sampler status on the screen, with the addition of menus to select commands. The operator could select menu items such as "3 liters", "drawer 17", "downward cast", "take the sample". The program would then combine the commands needed to perform this operation in a sort of batch file, sending each subsequent command upon receipt of a confirmation of completion of the previous command until the task was completed. It had the "intelligence" to prevent it from inadvertently taking another sample in a drawer already sampled (even though the status display told the operator it had been sampled). It would also stop the operator from taking too large a sample which might burst the storage bag in the drawer.

ENGINEERING TERMINAL: Early on it was realized that more operational information was needed by engineering to measure the sampler's performance. The QuickBasic program written for the ultimate user was adequate for his use, but did not provide enough information about how well the system was working (to confirm adherence to design goals) and, if something was not working, it did not show what was wrong.

The Basic program depended too much on specific commands and responses and would have been hard pressed to sort out the extra data from the underwater unit. It was therefore decided to use a standard terminal emulator software (Mirror or ProComm) at the surface when engineering was operating the system. Commands had to be sent manually by the operator in the proper sequence with no error checking for improper commands. This did provide, however, an excellent means of collecting performance data for future review and it allowed the user to try various modes of operation. Although the additional tasks imposed by the special engineering commands slowed down the controller's accomplishment of the functional tasks, it was not appreciable enough to affect performance. As an aside, the larger amount of data sent back did allow a better evaluation of any interference affect on the CTD data caused by the adjacent communication channel.

WATER SAMPLER CONTROLLER COMMANDS

COMMAND		RESPONSE	DESCRIPTION
A)	#WS	"CR"LF"	Water sampler in the open addressed state
"SET COMMANDS"			
B)	SRnn	OK"CR"LF"ETX"	Select Chamber Number nn with the rotary valve. Note, See Error Response.
C)	SSn	OK"CR"LF"ETX"	Sample n Liters of Water. Note, there is approximately a 5 second delay from the OK to the WS> response. Updates chamber sample status based upon position of rotary valve (see RC and CC commands). Updates volume measured value (see RV command). Note: See Error Response.
D)	SD	OK"CR"LF"ETX"	Toggle Position of directional valve. If at top move to bottom, if at bottom move to top. Note: See Error Response.
E)	SH	OK"CR"LF"ETX"	Return Rotary valve to the "home" position. Note, See Error Response.
F)	SE	OK"CR"LF"ETX"	Return directional valve to the "home" position. Note, See Error Response.
"DATA COMMANDS"			
G)	DS	nnn,cc,g,d,o,hhhhhhhhh	Read Status from the sampler where: nnn = Volume sensed by flow sensor for last sample collected in L*100. cc = Position of Rotary valve. g = Rotary Valve @ Home 0 = "No", 1 = "Yes" d = Position of Directional Valve "d" = T for "TOP" "d" = B for "BOTTOM" o = Directional Valve Home 0 = "No", 1 = "Yes" hhhhhhhhh = Read Chamber status. Data returned as 9 hex characters when converted to binary represent the present status of each chamber. A "1" represents sampled, a ")' represents empty. As an example 00007 means that chamber 0, 1, and 2 have been filled and chamber 4-36 are empty. Note: See Error Message.

COMMAND	RESPONSE	DESCRIPTION
	"CR"LF"ETX"	
		HEX 7 Binary 00000111 Chamber 0 Full Chamber 1 Full Chamber 2 Full Chamber 3 Emt
H) DA	bb.bb,ss.ss,pppp.p, tttt.t"CR"LF"ETX"	Read A/D convertor from sampler Where: bb.bb = Battery Voltage ss.ss = Sea Cable Voltage pppp.p = Pressure psia tttt.t = Tension psia
"RESET COMMANDS"		
I) RC Y/N	(Y/N)?"CR"LF" "CR"LF"ETX"	Clears chamber status table. Assumes draws and water have been removed from sampler. Verification via the RC command would result in 00000 value.
J) RP Y/N	(Y/N)?"CR"LF" "CR"LF"ETX"	Toggles power on/off to external sensors connected to command link.
"ERROR RESPONSES"		
K)	En"CR"LF"ETX"	The controller responds with an error code nn, where nn is per the following table: 0 Rotary Valve Failed to "Home" 1 Directional Valve Failed to "Home" 2 Memory Failure 3 Chamber Already Sampled 4 Invalid Command Received

TESTING AND EVALUATION

Laboratory and Dockside Component Testing

Bag Material Selection

In addition to being leak-tight and mechanically strong, the water sample containers must not allow the initial concentrations of dissolved substances in the water sample to be significantly altered during collection and storage. Contamination of the water samples by or through the container walls is always present to some extent, and cannot be eliminated completely. The processes of contamination include the removal of molecules in solution within the water sample volume by adsorption (adhesion of the molecules to the wall surface), absorption of molecules by the walls, or diffusion of molecules through the walls. Conversely, molecules not present in the originally sampled water may be introduced into the water sample by transport through or release from the container material. Therefore, it is important to establish the rate of contamination of candidate container materials, and then to assess how severe the contamination may be for a particular material in this application.

A number of materials were evaluated for possible use in constructing sample containers or bags. Based on initial tests discussed below, the most promising material for containers is a tri-laminate film consisting of 1.0 mil polyester - 0.7 mil aluminum and 0.1 mil polyester. (Note, 1 mil = 0.001 inches.) There are advantages and disadvantages in using flexible bags for sample collection versus the traditional rigid Niskin bottles.

ADVANTAGES:

- A bag surrounded by seawater as it is lowered or recovered does not have the compressibility problems of the Niskin bottle, which may leak ambient water into the sample as it is lowered after closing, or expel sampled water as it is recovered. The sample bag merely acts as a separator, allowing the water inside to compress or expand with the ambient pressure. Therefore, samples can be gathered reliably on the descent.

- Water can be drawn from a bag without introducing an air or gas headspace inside. As soon as a rigid wall container, such as a Niskin bottle, is opened for sub-sampling, gases begin exchanging between the seawater and the headspace. The resulting changes in dissolved gas concentrations are dependent on many factors, including the gas exchange coefficients, the time between opening the bottle and collection of the samples, the volume of the bottle and volume of water withdrawn for previous samples, the distance between the headspace and the area where samples are withdraw, the stratification of the seawater in the bottle, the amount of ships motion, and the gradient between the concentrations of the gases in the seawater and the headspace phases. In contrast, when sampling from flexible bags, the dissolved gas concentrations inside the bag should not change during the normal sampling processes, and the quality of the last water sample drawn should be as good as the first.

- The inside of the bag can be cleaned thoroughly during manufacturing (perhaps sterilized) and sealed until collection of the sample. Thus the inside walls are not exposed to contamination on board ship, or while moving through the water column prior to sampling.

- The seawater held in a bag is not in contact with large internal springs, O-ring seals, internal lanyards, etc. These components, which are present in standard Niskin bottles, can cause contamination problems for some chemical measurements.

- The permeable layer of tri-laminate which is exposed to the seawater can be made very thin (e.g. 0.1 mil). Thus dissolved gases or other material can only change with a small, fixed quantity of permeable material. For gases in 0.1 mil polyester, this exchange process is rapid, and the equilibrium amount of gas present in the wall layer can be calculated. The Niskin bottle has a 1 cm thick PVC wall which can pick up various amounts of gases and other contaminants from the atmosphere on shipboard and during shipping. The equilibrium time constant for gases in a 1 cm thin layer of plastic at normal temperatures is of the order of weeks to months. Therefore, during the relatively short period of flushing in the water column during a cast, the walls do not approach equilibrium with the dissolved gases in the surrounding water. Following closure of the bottle, the walls will continue to take up from or release gases to the sample. This amount is variable and strongly dependent on the amount of time that the sample remains in the bottle, the initial distribution of gases in the bottle wall before closing and the diffusion coefficient for the gas.

DISADVANTAGES:

- The bags must be manufactured under ultra-clean conditions. Also they must be able to be stored for months in an environment where there can there be no slow contamination via diffusion through the walls, seams or valves before being used.

- Since it will probably not be feasible to test each bag prior to use, rigorous quality control must be maintained during manufacturing, or during any post-manufacturing cleaning process.

- Surface adsorption onto the inner plastic layer and aluminum layer may be a problem for some types of measurements. Niskin bottles are flushed with large volumes of water before closing, and active contamination sites are filled prior to closing. An unflushed bag may have active sites which remove significant amounts of dissolved species such as phosphate or trace metals from the water sample. The aluminum layer may also be reactive with some species such as oxygen. Tests indicate that the effects of adsorption by the inner polyester and aluminum layers are small for CFCs and nutrients over periods of at least several hours. The results of the tests of the bag material with dissolved phosphate are especially encouraging, since this nutrient is typically the one most susceptible to adsorption losses using existing sampling methods.

- Each bag is unique and used only once. If bag manufacturing is not uniform, or an individual bag is contaminated, it will not be detected until use. A Niskin bottle is reused, and a log of bottle history can be maintained to indicate problems or deviations due to individual bottles.

Laboratory Bag Testing

CHEMICAL REQUIREMENTS: The WOCE requirements for the water samples in 1989 are given in Table 6. Our goal was to obtain maximum contamination levels of samples obtained with the integrated water sampler (normal water

sampling procedures with a four-hour cast time and one-hour wait on deck) of less than those listed in Table 7 below, which is a 1990 update, and consistent with or better than Table 6.

TESTS: Laboratory testing focused on the suitability of materials for use in helium and chlorofluorocarbon (CFC) sampling. Helium has a very high diffusion rate through many materials, and was used to serve as a check on the maximum rate of gas transfer through container walls and seams. Adsorption and release of trace levels of CFCs (especially Freon-11) from container walls and seals has been a severe problem with Niskin samplers.

The transfer rates of gases through plastic films vary widely depending on the type of gas and the composition of the film material. Based on permeability data, calculations indicate that even for low-permeability plastics, the rates of gas diffusion through thin-walled bags is unacceptably high. For example, the flux of oxygen from the atmosphere into oxygen-free water stored in a 10-liter spherical bag with a surface area of 2250 cm^2 constructed of 1 mil thick Saran film can raise the dissolved oxygen concentration by about 0.006 ml/liter/day.

A number of thin tri-laminate (polymer-aluminum-polymer) films which have much lower permeabilities than mono-layer polymer films are commercially available. In such multi-laminate films, the addition of a thin (0.5 mil) aluminum layer can reduce the overall permeability of a film by a factor of 1000 or more.

Samples of several multi-layer films were obtained and tested for possible bag construction.

FREON TESTING: Due to the extreme sensitivity of chlorofluoro- carbon (CFC) or Freon measurements to even trace levels of contamination, emphasis was placed on determining the suitability of various materials for use in collecting seawater samples for dissolved CFC analysis. It was felt that bag materials with contamination rates of the order of the present limit of detection (5 x 10-15 mole/liter) would be reasonable candidates not only for Freon samples containment, but also for the measurement of other dissolved chemicals (gases, metal ions, nutrients).

CFCs (as well as other gases) can exchange between the permeable material in the walls of the container and the water sample. As a result, wall materials which initially contain high levels of CFCs can badly contaminate a low-CFC sample. Conversely, if the walls of a sample container are initially CFC-free, dissolved CFCs can be lost from the sample by dissolution into the walls. In multi-laminated materials, these effects can be reduced by choosing a thin inner layer of material with low CFC solubility. (In commercially available tri-laminated materials, the minimum thickness of the inner layer required to form a seam by heat sealing techniques is typically about 0.1 mil).

Laboratory tests were performed to determine the solubilities of Freon-11 and Freon-12 in samples of various plastic films. Samples of aluminum, polyester, Saran, Surlyn, nylon, polyvinylchloride (PVC), and polypropylene films of various thickness were obtained from Battelle-Columbus and tested at WHOI for their ability to absorb or release Freon-11 and Freon-12. At 25°C,

Table 6: Requirements for WOCE Water Sampler

T: Deep Sea Reversing Thermometers (DSRTs) are available with 0.004-0.005°C accuracy and 0.002°C precision for expanded scale instruments. Reliable multiple CTD-sensors have the potential to eliminate the standard use of DSRTs. Digital DSRTs do not require long soaking times and can serve as a means for calibration and performance checks.

S: 0.002 PSU accuracy is possible with Autosalinometers and great care taken to monitor Standard Sea Water. Accuracy with respect to one particular batch of Standard Sea Water can be achieved at 0.001 PSU. The Autosal is better than 0.001 PSU precision, but great care and experience is needed to acheive these limits on a routine basis as required for WOCE. Laboratories with temperature satability of 1°C are necessary for propoer Autosal performance.

O_2: accuracy <1%. Some laboratories achieve 0.5%, which is desirable for deep sea work and hece required for WOCE, and 0.1% precision, with improvements due to developements in 'new' end-point techniques.

NO_3: approximately 1% accuracy and precision full scale. The standard is probably appropriate for the WOCE Hydorgraphic Program.

PO_4: approximately 1-2% accuracy and precision full scale. It is recommended that standards for nutrients be developed.

SiO_3: accuracy approximately 3% and full-scale precision. Strong opinion exists that laboratory temperature fluctuations cause significant errors, because 1°C laboratory fluctuations yields appromately 1% change in SiO_3.

^3H: 1% accuracy and 0.5% precision with a detection limit of 0.05 tritium unit (TU) in the Northern hemisphere, upper ocean and 0.005 TU elsewhere.

δ^3He: 1.5 per mille in accuracy/precision in isotopic ratio; absolute total He of 0.5% with less stringent requirement for use as a tracer (e.g. He plume near East Pacific Rise.)

CFCs: accuracy/precision at approximately 1%, blanks at 0.005 pM with best techniques. Investigation of CFC collection and analysis technology appropriate to these quality levels on 'mass production' basis needed.

^{14}C: 3 mille via beta-counting on 200-liter samples; 5-10 per mille with Accelerator Mass Spectrometer.

^{85}Kr: detection limit of 1% of surface concentration; precision of 4% decreasing to 25% for samples near the detection limit.

^{39}Ar: precision of 5% of surface value; minimum detectable amount about 5% of surface value.

^{228}Ra: 5% accuracy/precision.

$\delta^{18}O$: may be used in high latitudes; these should be measured with accuracites of 0.02 per mille.

Adapted from Table II.A.4 in World Ocean Circulation Experiment, U.S. WOCE Implementation Report Number 1, March 1989.

Table 7: Maximum Contamination Levels Allowable on WOCE Water Samples

Dissolved Gases	Oxygen - 0.5 μM/kg Freon-11 and Freon-12 - 0.005 pM/kg Helium - 8 pM/kg
Salinity	0.001 PSU => <1.0 cc water leakage
Nutrients	Silicate - 0.1 μM/kg Phosphate - 0.01 - μM/kg Nitrate + Nitrite - 0.03 μM/kg
Isotopes	Tritium - 0.001 T.U. (deep samples)

Freon-11 solubilities in these samples ranged from a factor of 90 (for polyester) to 300 (for Surlyn) times higher than seawater. Freon-12 solubilities were typically about 50% lower than those of Freon-11 in the materials tested.

Clean-up Tests - Small pieces of the samples (several square cm) were flushed with pure nitrogen for several days (a freon-free environment), then placed in syringes with water free of CFC. Measurements of the increase in CFC in the water were used to estimate how effective the initial nitrogen flushing process was in removing traces of CFC from the film. After exposure to clean nitrogen for several days, all of the above materials continued to release trace amounts of CFCs (especially Freon-11) into the water samples. This cleanup process is relatively fast: for the 0.1 mil polyester film at 25°C, more than 90% of the Freon-11 initially present in the film was removed in about 3 hours. Removal rates are about 100 times faster at 80°C. When scaled to the film-surface-area/ water-volume ratio expected for 10-liter bags, the observed rates of release of Freon-11 from polyester material exceeded desired blank levels in a sealed bag stored longer than about a week.

Freon Release Tests - Small pieces of the samples of the above materials were exposed to high levels of Freon-11 and Freon-12 (1000 x modern clean air concentrations), then placed in syringes with CFC-free water for various lengths of time (minutes to days). The rates of release of Freon-11 and Freon-12 were greatest for polypropylene and least for polyester.

Adsorption Tests - The aluminum substrate in the bag could represent an active surface for adsorption. The polyester liner between the aluminum and sample water acts as a diffusive barrier to increase the length of time the sample can be stored in the bag before adsorption becomes significant. Tests with 1 mil thin polyester indicate that the diffusive time scale is in the range of 4 to 8 hours. By going to a 2 mil thick material, we would gain as the square of the thickness and would obtain a 16-32 hour storage time.

Absorption Tests - The dissolution of the water sample's Freon into the initially Freon-free plastic will deplete the sample. Samples were then flushed with pure nitrogen and placed in syringes containing water of known dissolved Freon-11 and Freon-12 at moderate concentrations. No significant amount of absorption of dissolved CFCs onto the surfaces of polyester or aluminum could be detected for examples exposed to water for a period of 2 days. Small decreases in dissolved Freon-11 and Freon-12 concentrations were observed in some water samples exposed for several days to the other films. For a 0.1 mil polyester film on a 10-liter bag, this would lead to a predictable loss of about 0.5% of Freon-11 and 0.25% of Freon-12 to the inner polyester lining. These results are more favorable than the potential error introduced by diffusive exchange of a sample with the 1 cm thick PVC walls of a Niskin bottle.

HELIUM TESTING: The proposed tri-laminate bag uses an aluminum diffusion barrier sandwiched between two polyester layers (polyester was chosen as the inner plastic material since it was least contaminating for freons). The diffusion coefficient of helium in aluminum is immeasurably small, so the rate of diffusion is controlled by the number of pinhole leaks in the aluminum layer and in the seams. Aluminum foils thicker than 0.7 mil essentially have no pinholes. The seams have a small net area, and can be made sufficiently deep to be a good diffusion barrier. The final proposed bag material consists of a multilayered laminate consisting of 0.49-mil polyester outer film, a 1.0-mil aluminum film, a second 0.49-mil polyester film, and a 0.2- to 0.3-mil heat-sealable inner coating.

Tests were run on bags of a tri-laminate of 0.1-mil polyester, 0.75-mil aluminum, and 1.0-mil polyester, with the 0.1-mil polyester layer on the inside. Since the aluminum is sufficiently thick, the only leakage path should be through the seams, and the only source of error should be the capacity of the inside seal layer to give off or take up helium. The volume of this seal layer is 0.6 cc and the solubility of helium in the plastic is similar to that of water, so the total error is less than 0.01%.

Tests were made by exposing small bags of water (200 cc water with 42 cm seam length) to varying helium atmosphere for certain periods of time. The experiment was very sensitive due to the large seam-to-volume ratio, so the results were scaled up to the full size 10-liter bag with 145 cm seam length, using a typical storage time of two hours. This estimated time the water sample will spend in the bag before subsampling includes 45 minutes to rise from 5000 m depth at 2 m/sec rate, 30 minutes before retrieval of the sample and another 45 minutes for sampling. The scaled results are given in Table 8 below and are the expected percent equilibrium of the sample with the environment.

If the highest helium loss listed (0.1%+0.01%) is selected as a worst case leakage rate, it would introduce an error of 0.05% in a deep Pacific sample (with δ^3He of 50%), i.e. one third of analytical error.

Therefore, the seams, when properly formed, present an adequate diffusion barrier to prevent significant helium leakage, but small imperfections in the seam path may present occasional leak paths (which probably caused the measurable contamination level observed in experiments 1 and 3 above). Therefore, even with no improvement in the seam sealing technique, there is no real problem effecting helium measurements.

OXYGEN AND NUTRIENTS: Oxygen may be lost through diffusion through the plastic and by oxidative loss on the aluminum substrate. These are not a problem because the diffusive time scale through the polyester layer is too long. Bagged seawater tests have shown that the aluminum, protected by the plastic layer, still appears shiny after several months.

Adsorption of nutrients (phosphates and nitrates) by possible chemical reaction with the aluminum was evaluated by W. Jenkins (WHOI) and J. Jennings (OSU) during the 10° North Pacific Ocean Survey in April 1989. For this test, several assorted sample containers were filled with seawater samples collected in the mixed layer, at the nutrient maximum, silicate maximum and near the bottom. The containers were made from a tri-laminated material consisting of a 0.1 mil polyester inner sea layer, a 0.7 mil aluminum foil middle layer and a 1.0 mil polyester outer layer. Three container sizes having different seam lengths, volumes and surface areas were used as listed in Table 9. The largest containers were made with only two seams, whereas the medium and small containers had three seams. Characteristics of a 10-liter design container are tabulated as well.

Nutrient samples were drawn from the Niskin bottles, then processed in normal fashion using standard laboratory techniques. Duplicate nutrient samples were drawn into normal, high density polyethylene containers at the same time as into the tri-laminate "bags", and both types were stored under refrigeration for 2.5 hours. No special precautions were taken with the sample containers (bags), nor was any pretreatment used. The bags were simply rinsed and filled directly from the Niskin bottle, the top folded over three times and clipped. After the storage period, the samples were decanted into the standard analysis vials and analyzed in duplicate. The analysis results are summarized in Table 10 and are the average of duplicate analyses of water from the same bag. Sample analyses were alternated, interspersed, and reversed to avoid bias.

Average residual differences (tri-laminate minus polyethylene) are listed below in Table 11 with uncertainties expressed as the 2-sigma standard deviation of the mean.

Only phosphate shows any significant average difference, but at a level which is small compared to normal analytical errors, and probably is attributable to contamination introduced by handling of the sample container prior to sampling (no particular precautions were taken). This is consistent with the somewhat higher residuals exhibited by the small bags. To scale the results up to the WOCE 10-liter design container, we used the geometric mean volume/sea surface area factor of the containers, which provides a more conservative estimate of the scale of the problem (choosing the volume to seam-length factor results in a smaller estimate). No significant differences were observed for any of the nutrients, except phosphate, which showed a barely detectable offset which is of no consequence for ocean tracer work. The proposed tri-laminate bag material is therefore viable for the WOCE water sampler.

Water Acquisition Subsystem Tests

For initial testing of the water acquisition system, a structural mockup was fabricated to hold the components of the water acquisition subsystem. The tests were configured to test the rotary valve assembly, pumping system, sample container with inlet valve, and drawer. During the tests, the structural mockup was lowered into to test pool to depths of 33 feet.

Initial testing showed that all of the components worked, but several of them needed refinement to improve performance and reliability as described below.

The original floating gasket seal in the rotary valve assembly was prone to separating from its body which reduced differential pressure and caused high drag loads. The floating gasket seal design was changed to a spring loaded, Delrin seal shaped to fit closely to the inner surface of the fixed tube. Tests with this design showed good results.

The positioning of the rotary valve was inconsistent. This problem was first thought to be due to the high torque requirement the floating gasket seal put on the rotary valve motor. When the moving seals were redesigned, the torque requirement on the drive motor was reduced to approximately a third of the motor capacity, yet the positioning problem still persisted. The rotary valve is turned by a stepping motor, that is coupled to the rotary valve with a drive belt. It is now believed that when the drive motor is de-activated (after stepping to its next position), tension on the drive side of

Table 8: Results of laboratory tests to determine helium loss through seams of tri-laminate water sample containers

Experiment Number	Type of He Atmosphere	Duration	Scaled Effect
1	9.5 fold enrichment	2 hours	0.1 $\pm$ 0.01%
2	66 fold enrichment	2 hours	< 0.002%
3	He-free atmosphere	5 hours	0.07 $\pm$ 0.03%
4	200,000 fold enrichment	2 hours	0.014 $\pm$ 0.0002%

Table 9: Physical Dimensions of Sample Containers Used for Nutrient Tests

-	SMALL	MEDIUM	LARGE	DESIGN BAG
Width (cm)	3.8	8.0	14.3	---
Length (cm)	15.2	15.2	21.6	---
Number of Seams	3	3	2	---
Volume (cc)	30	100	600	10000
Surface Area (cm^2)	117	243	618	2247
Seam Length (cm)	34	38	36	142
V/A (cm)	0.26	0.41	0.97	4.45
V/1 (cm^2)	0.88	2.63	16.7	70.4

Table 10: Laboratory Results of Nutrient Measurements in the Pacific

Polyethylene Containers				Tri-Laminate Containers			
Sample Depth (m)	Phosphate	Nitrate	Silicate	Cont. Size	Phosphate	Nitrate	Silicate
10	0.353	0.9	1.3	M	0.35	0.9	1.3
50	0.36	1.0	1.4	L S	0.36 0.37	1.0 1.0	1.4 1.4
800	3.28	43.9	78.3	M S	3.29 3.31	44.1 44.1	78.4 78.5
1000	3.29	44.0	98.3	M	3.30	38.6	98.3
3000	2.77	38.6	158.1	M	2.78	35.0	157.9
5000	2.48	35.0	136.9	L	2.52		136.8

Table 11: Errors in Sample Comparison Listed in Table 10

Analysis	Actual Difference	Scaled Difference
Phosphate	+0.013 ± 0.008	+0.001 ± 0.001
Nitrate + Nitrite	+0.005 ± 0.06	+0.005 ± 0.006
Silicate	+0.01 ± 0.08	+0.001 ± 0.008
Nitrite	-0.01 ± 0.08	-0.,001 ± 0.001

the belt relaxes and the motor 'loses' a few steps. In order to rectify this problem, a simple belt tightening device was designed and built. This device maintains the tension on the slack side to equal the drive side of the belt. Even though this relieved the mis-stepping, it was decided that an absolute positioning sensor needed to be attached to the rotary valve to provide information on its angular location.

After initial component testing of the drawers and inlet valves of the water container assembly, improvements to the design were made to allow easier operation, simpler construction, and improved performance. The magnets in the inlet valves are bonded into place, doing away with the reliability concerns of the previous set-screw design. The valve is designed with a step such that when the magnet is bonded flush with the valve body, the cracking pressure of the valve is 7 psi. This design step reduces the trapped volume between the poppet and the valve body to below the 1.5 to 4 cc found in previous static leakage tests of the valves when subjected to ambient pressures of 9000 psi. This design also simplified the assembly procedure of the valve.

One area of concern was whether or not the poppet seal would have any permanent setting problems. Tests at Battelle have shown that no permanent set problems exist with the selected neoprene seal when compressed 25% and exposed for 6 hours to 140 °F (or for 18 hours at 125 °F), or for approximately one month at room temperature.

Initial filling tests, show that the tails of the bags come times blocked drawer outlet prevent the bags from filling completely. A bag retaining plate was designed and added to the water container assembly to prevent the bag tails from blocking the pump suction.

The poppet valves are made of steel with a coating of Scotch-coat epoxy. Samples of these poppet valves were tested by a WHOI chemist. The tests resulted indicated that the coating doesn't present a contamination problem.

The initial bag configuration was a near square (15" x 15") bag, but filling tests resulted in pinholes in the aluminum layer reducing the effectiveness of the bag material to retain dissolved gases. By testing different bag configurations, it was found that shape and size had a major impact on the amount of pinholes created when the bag is filled. Many bag shapes were manufactured from the bag material candidate, filled with water, drained, and inspected for pinholes. The optimum designs were those which held the greatest amount of seawater with the least amount of pinholes. A secondary design consideration was to keep the total internal surface area as low as possible to allow the shortest possible nitrogen purge times. The selected candidate shape is a long rectangular shape (13" x 42") which folds back on itself in the drawer to provide four separate pockets.

Dock-side tests of water sampler at WHOI were conducted on March 9, 12, 13, and 14. During testing, it was determined that the pump motor controller did not perform properly at cold temperatures. Apparently the electronics of the controller do not permit adequate battery power to energize the motor when subjected to low temperatures. Proper motor speed (e.g. 3000 Rpm) and opening of inlet valve, in cold water, is only possible when the motor is allowed to run for 20 to 30 seconds, thus warming up the electronic components. Recognizing this problem, the field tests were conducted by running the motor much longer than the typical 5-sec filling time obtained in warm (70°F) water tests. After the shake down cruise, the motor, pump and motor controller were returned to the LandSea, the manufacturer, in Buffalo, N.Y. Modifications were made to the motor controller. An acceptance test was conducted demonstrating that the motor could generate 0.5 hp (at 3600 RPM) output at the shaft while the motor controller was at 2°C.

Water Sampler Terminal Velocity

A series of terminal velocity measurements of the underwater unit were made at the WHOI pier. The upper and lower fiberglass shrouds were bolted onto the frame. A lead weight was bolted into the frame near the calculated center of gravity to simulate the weight and buoyancy of all of the various pressure cases, etc. A sheet metal shroud was wrapped around the cylindrical portion of the underwater unit to simulate the surface when all of the drawers and lower shrouds were in place. Syntactic foam blocks were bolted in place under the top hemispherical fairing.

A low inertia wheel with small diameter Kevlar line wound on it was mechanically linked to a precision rotary potentiometer. The output of the potentiometer was recorded on a strip chart recorder. The Kevlar line was attached to the apex of the underwater unit. The underwater unit was suspended from a quick release hook over a well in the WHOI pier. When the release hook is tripped, the Kevlar line causes the wheel to spin and the potentiometer records line out as a function of time (terminal velocity).

The free fall of the sampler was arrested short of impact with the bottom (at 60 feet) by 50 feet of nylon line and a float. The float stops the underwater unit, and the nylon line is then used to haul it all back to the surface. This test was repeated four times, and the resulting terminal velocities were averaged. The freefall terminal velocity of the underwater unit as tested was 2.5 m/sec or 152 m/min.

Test and Evaluation Cruises

Shakedown Cruise

In preparation for the evaluation cruise, a shakedown cruise was conducted. The R/V *Oceanus* departed Woods Hole at 0830 on March 15, 1990, with a scientific party of 11, including 8 project personnel from WHOI, 2 project personnel from Battelle, and an additional WHOI scientist conducting ancillary tests. The cruise track extended from Woods Hole, southward across the continental shelf, and into water depths of approximately 2400 m. the majority of the testing was conducted offshore of the continental shelf, between 1900 h on March 15 through 1300 h on March 16. The weather was extremely cooperative, with seas less than 3 ft and idle winds. The R/V *Oceanus* returned to port at 2030 on March 16.

The water sampler was deployed a total of 4 times. Two shallow deployments were made on the continental shelf, and two profiles to roughly 2100 m were made on the slope (see tables of Cast 1 and 2 in Appendix C for data on these profiles). Winch speeds were varied over the range from 0.5 to 2.0 m/sec. No problems were encountered with the Markey winch on the vessel. (Note, that over the 2000 m profiles, the maximum attainable descent and ascent speeds with the winch were roughly 130 and 105 m/min, respectively.)

Below we provide a list of the significant results of the shake down cruise testing:

HANDLING SYSTEM: The temporary handling apparatus proved to be adequate for safe launch and recovery of the sampler; the unit was launched and recovered four times without damage to equipment or personnel. We expect that safe handling can be accomplished in moderate seas with this equipment.

WINCH, WIRE, AND TERMINATION: The Markey DESH-5 winch had no difficulty with the underwater unit in the water, in air without samples, or in air full of water.

No problems (kinks) were encountered with the 0.322-in conductor wire due to the use of the water sampler.

The specialized termination exhibited no problems or wire extrusion. An at-sea retermination was accomplished in less than two hours. (The retermination was necessary because of a kink in the wire caused by the sheave on the ship's hoisting arm.)

UNDERWATER UNIT: When the underwater unit is lowered into the water it does not float; in fact, it maintains a vertical orientation regardless of lowering rate. Thus, the unit is well ballasted and entrapped air does not cause instability or slack wire when the unit is emersed without prefilling.

It takes roughly 30 sec for the majority of the air to vent from the underwater unit as it enters the water, but this does not affect stability. A rapid lower to 10 m was made to determine whether the inlet valves would open due to reduced pressure in the drawers caused by air still trapped within the venting drawers. None of the six drawers with evacuated sample bags collected water during this test.

Tilt and spin sensors within the underwater unit indicated that the unit tilted on average less than 5 degrees during lowerings at 1.5 m/sec and less than 10 degrees at lowering speeds of 2.0 m/sec; observed tilt was less than 5 degrees during upcasts. Spin was minimal throughout the tests, typically less than 10 turns per deep cast.

The wire-tension indicator on the Markey winch revealed tensions that were consistent with empirical predictions. The tension cell within the underwater unit appeared to be malfunctioning during the casts.

WATER ACQUISITION SYSTEM: The rotary valve successfully accessed all 36 sample drawers during each of the two deep casts without a single positioning error. The location of the rotary valve was confirmed for each sample drawer. By intentionally not filling some of the drawers, it could be determined that the rotary valve was not accessing multiple drawers during sample collection.

Full 7 L samples were collected while the underwater unit was (1) held at a constant depth, and (2) descending and ascending at speeds up to 1.5 m/sec.

Full 7 L samples were collected at a variety of depths between the surface and 2000 m. Also, empty samples containers were cycled over an entire 2000 m cast with no entry of water through the inlet valve, expect for one "freak" container (or bag).

Some containers were intentionally only partially filled by limiting the pumping duration. Because these containers did not fill completely, it appears that the dynamic pressure differential created during ascent/descent was insufficient to keep the inlet valve open when the pump was turned off.

The flowmeter readings did not give an indication of a successful sample bag filling operation.

The exhaust valve position shifted to its appropriate setting.

CTD SYSTEM: A WHOI-owned EG&G/NBIS Mark III-B CTD was used for the tests. This unit was modified to accept data from a tension cell, a compass (spin detector), and a 2 axis tilt sensor, all of which were mounted in the

underwater unit (see Engineering Module section above). Preliminary indications were that the quality of the CTD data was not degraded by the altimeter nor activation of the water sampler control unit.

COMMUNICATION SYSTEM: The communication system for the water sampler worked well with few, if any, errors in the two-way communication. Activation of the rotary valve, monitoring of the batteries, interfacing with the CTD data stream, and communication with the altimeter were all operable.

POWER SYSTEM: The 48-volt battery pack within the underwater unit was fully capable of driving the water sampler components. In fact, each of the two 2000 m profiles was equivalent in pumping time (and battery usage) to three profiles (3 times 36 samples collected with 5 sec pumping times). A separate battery pack was used for the second profile. Also, the battery packs were recharged aboard the vessel.

No grounding problems were encountered. Handling personnel experienced no electrical shocks during deployment and recovery operations.

ALTIMETER: The altimeter was temporarily mounted on the outside of the underwater unit for this test. The communication interface to the altimeter was operational for changing the ping interval of the altimeter and obtaining height-off-the-bottom data. However, the height information was not reliable and the control of the altimeter output power apparently was not working. The unit was returned to the manufacturer for repair and checkout.

The graphic recorder on the R/V *Oceanus* was used to record the received acoustic signals from the altimeter (independent from the direct interface through the water sampler control unit). Good bottom-return signals were received regardless of the depth of the underwater unit (1-way travel distance of roughly 2400 m). The direct signal from the unit to the vessel was weak due to the downward looking orientation of the altimeter's transducer. These results indicated that the altimeter's acoustic output is strong but the acoustic pulse detecting circuit with the altimeter has problems.

PREPARATION OF WATER ACQUISITION SYSTEM: A single person was able to install the 36 drawers into the water sampler in less than 1/2 hour. (This was done twice by two different "semi-skilled" persons.)

Evaluation Cruise, Leg 1 - Woods Hole to Bermuda

The purpose of the evaluation cruises was to conduct at-sea tests to demonstrate that the prototype water sampler performed as expected and met design specifications.

The purpose of Leg 1 was to conduct engineering and hydrographic tests of the Water Sampler.

PARTICIPANTS ON LEG 1 OF EVALUATION CRUISE:

	Individual	Affiliation	Responsibility
1	H. Berteaux	WHOI	Chief Scientist
2	R. Millard	WHOI	Scientific Coordinator
3	J. Kemp	WHOI	Water Sampler Deployment
4	A. Fougere	WHOI	Control Electronics - Sr. EE
5	C. Eck	WHOI	Control Electronics - EE
6	S. Smith	WHOI	Control Electronics - EE
7	P. O'Malley	WHOI	Water Sampler Deployment
8	G. Bond	WHOI	CTD Operation

8	C. McMurray	WHOI	CTD Data Acquisition
10	G. Knapp	WHOI	Salinity Analyses
11	P. Bouchard	WHOI	Research Assistant
12	C. Albro	Battelle	Water Sampler Compon. - Sr. OE
13	A. Shultz	Battelle	Water Sampler Compon. - ME
14	K. Schleiffer	Battelle	Water Sampler Compon. - ME
15	R. Williams	Scripps	Physical Oceanographer

SEQUENCE OF EVENTS:

<u>Monday</u> 0800 EST April 16. Depart Woods Hole, Massachusetts

Six previously used sample bags were installed into the underwater unit and a shallow depth opening test (cast A) was conducted. All six bags contained water indicating that they opened (All cast data are listed in Appendix C), but they were not full. Looking at the bags within the drawer, it looked like the overlay of the folded bags may have prevented full bags.

<u>Tuesday</u> April 17

Thirty new sample bags were assembled (the assembly procedures are discussed above in the Sea Water Acquisition Subsystem section) and installed in the underwater unit with the six used sample bags from cast A. During Cast B, station OC29D002, the underwater unit was lowered to 3600 m at speeds up to 60 m/min. The results are summarized in Table 12 below. Of 16 sample bags pumped, only 3 were full, 7 were partially full, and the other 5 were empty. Of the 20 unpumped bags and the 5 "empty" bags, the leakage into the bags ranged from 1 cc to 85 cc. The two bags with 1 cc leakage exhibited a ridge of bag material around the poppet. During the cast, the altimeter successfully acquired and tracked the distance at the bottom. A comparison of altimeter and CTD depths from pressure is given in Table 13.

During Cast B, the end cap separated from the rotary valve preventing the controller from knowing where it was. Before the next cast it was repaired and checked out.

Fig. 14 shows unedited, processed, summary plots for Cast B - Station OC29D002. A fresh water layer with a salinity maximum and maximum temperatures seen at about 120 m depth. Temperature and salinity decrease to the maximum depth of 3715 m. The dissolved Oxygen profile shows a minimum at 300 m. The number of points averaged that were averaged together in the 2 m values plotted. The slower lowering rate in the upper 300 m and lower 200 meters is evident as greater number of samples averaged. A blowup of the 200 meter section from 2000 to 2200 meters, Fig. 15, shows that the structure of the sigma theta (Potential Density) profile can be related to the number of points being averaged, or the lowering rate. Minimums in the sigma theta are correlated with minimums in numbers of points averaged (high fall rate). The structure in the sigma-theta profile comes from the salinity record and is not evident in the temperature profile. The variations in the number of points are directly related to the wave activity and the roll of the ship being transferred down the wire to the underwater unit, and affecting the results. Note that there are two data drop-outs where data was not obtained and the number of points averaged drops to zero. The first was just above 2500 m depth and the second near the bottom of the profile.

<u>Wednesday</u> April 18

Twenty-four new sample bags were assembled and installed into the underwater unit. Eight of the sample bags were attached to the inlet valve

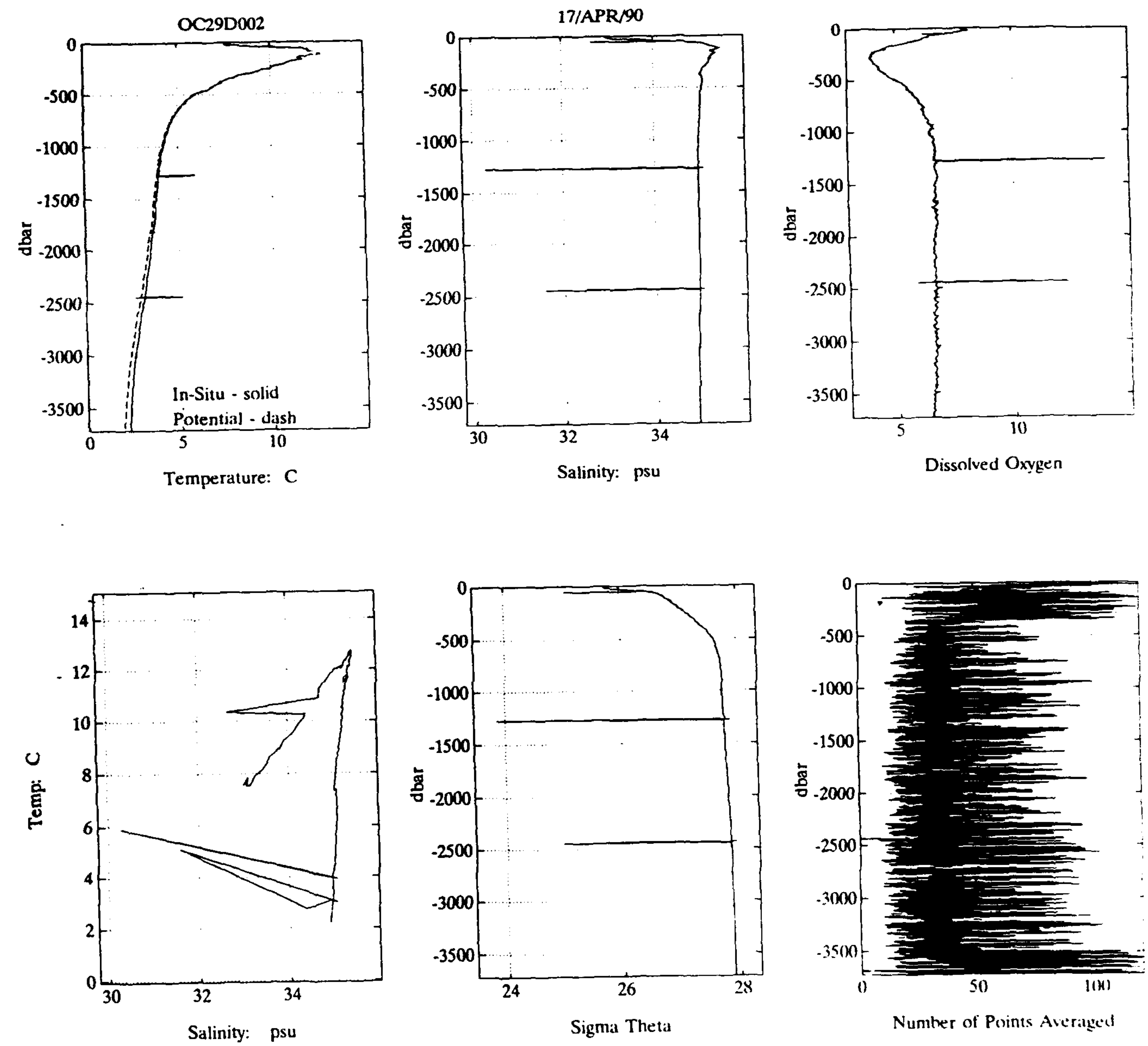


Figure 14: Summary Plots of Profile B - Station OC29D002

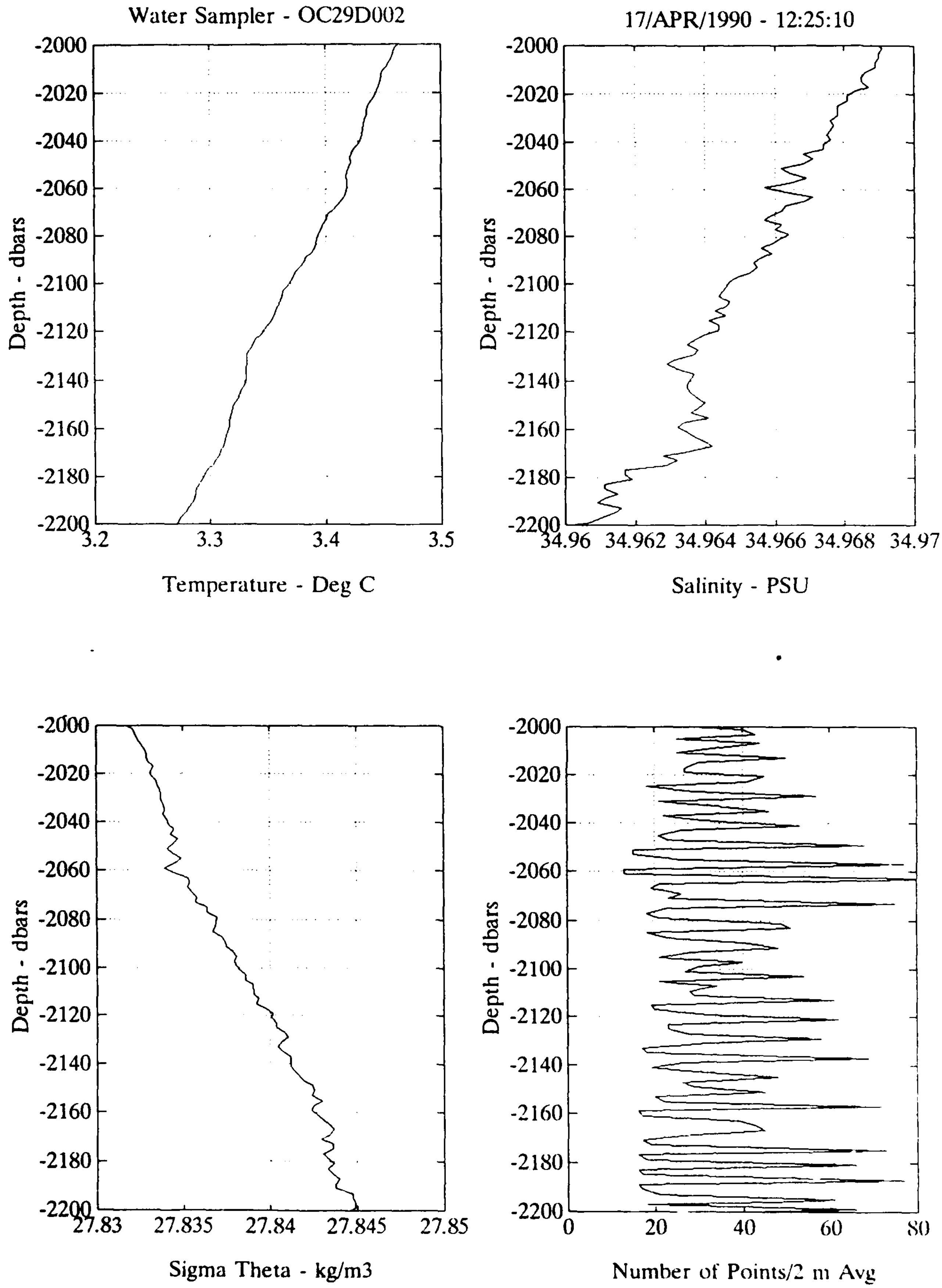


Figure 15: Summary Plots of Profile L - Station OC29D014

body with double sided tape covering all of the valve body. The other 16 bags were attached with a 3.6" diameter double sided tape. These two methods of attachments were tried in an attempt to reduce the leakage problem.

Conducted Cast C was made to 4200 m with winch speeds up to 60 m/min. Of 18 sample bags pumped, 9 were full, 3 partially full, and the other 6 were empty. Of the 6 unpumped bags, the leakage into the bags ranged from 2 to 31 cc. In general, the full taping did better. During the cast, the altimeter successfully acquired and tracked the distance at the bottom.

Cast D was made to 4500 m depth with 18 new sample bags. Only 5 of the 18 pumped bags had any water (maximum collected was 1.5 L).

Thursday April 19

Conducted Cast D1 to 10 m with 6 sample bags. All 6 bags were full.

Conducted Cast D2 to 500 m with 6 sample bags. Five of the sample bags were full.

Conducted Cast D3 to 1200 m with 7 sample bags. Six of the sample bags were full.

To increase the pumping differential pressure, the top of each drawer was taped and a skirt was added around the rotary valve pump inlet.

Conducted Cast D4 to 3000 m with 13 sample bags. All the sample bags were pumped with one bag being full, 7 partially full, and the other 5 were empty.

Thirty six new sample bags were assembled and installed into the underwater unit. A 1/8" rubber gasket was added to the back of 5 drawers to help increase differential pressure.

Conducted Cast E to 4000 meters. All the sample bags were pumped. Seventeen of 22 bags sampled at 1200 m or less were full. Only 2 of 14 bags sampled at greater than 1200 m was full.

Friday April 20

Conducted Cast F to 1200 m with 18 new sample bags. This cast was designed to evaluate the effect that water temperature over time had on the filling of sample bags. At the start of the cast, two sample bags were pumped for 5 seconds. Both were filled with more than 5 L of water. At 1200 m, eight pairs of sample bags were pumped (one for 5 s and other for 10 s) with the first pair pumped 90 minutes before the last pair. Generally, the 5 second samples collected less water, but pump failures occurred after 30 minutes at 6°C.

Conducted Cast G to 4000 m with 36 new sample bags. All thirty six sample bags were pumped for 10 s. Eighteen bags had greater than 5 L, 9 were partially filled, 9 failed to fill. Eight of the failed bags were cut open and leakage volume was measured. Amounts varied from 1 cc to 150 cc.

Saturday April 21

Conducted Cast H to 5 m with 12 new sample bags. For this cast, the underwater unit was lowered through the air sea interface rapidly to test for leakage caused by wave slap. During the launching process, the underwater unit was pushed nearly horizontal by a passing wave. The water leakage was

Table 12: Cruise 219 NSF Water Sampler Cast Log, Cast B

Cruise 219 NSF Water Sampler Cast Log													
Cast:	B					Date:	17-Apr-90			Time in:	8:40		
Battery Set Used:			A										
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Volume	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Collected	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(L)	(ml)	Remarks
1	3	3	2	8	8	-0	10	7.6	49.6	825	3.5		[1]
2	33	33			8	-0						16	[1]
3	35	35	4	8	16	-0	10	7.6	49.4	476	1.8		[1], leaky valve
4	27	27	6	8	24	-0	10	7.6	49.3	988	7.0		e
5	37A	37A	7	8	32	-0	10	7.6	49.2	314	6.0		[1]
6	16	16	8	16	48	-0	10	7.6	49.4		7.4		ran pump twice
7	15	15	21	8	56	-60	225	10.4		223	1.8		[1]
8	39	39	21	8	64	-60	241	10.1		416	0.0	5	
9	28	28	22	8	72	-60	267	9.5		178	6.5		[1]
10	5	5	22	8	80	-60	255	9.3		111	2.5		OLD BAG
11	23	23	22	8	88	-60	295	9.0		156	0.0	25	[1]
12	2	2	23	8	96	-60	309	8.5			0.0	40	[1]
13	17	17	23	8	104	-60	326	8.2	49.4	129	0.0	25	[1]
14	20	20			104	-60						80	[1]
15	7	7	33	8	112	-60	800	4.6	49.3	258	3.0		[1]
16	13	13	47	8	120	-60	1600	3.8	49.0	252	3.4		[1]
17	29	29	62	8	128	-60	2400	3.1	48.8	195	4.5		[1]
18	18	18			128	-60						70	
19	19	19	85	8	136	-30	3600	2.2	48.5	142	0.0	1	[1],[2]
20	32	32										40	
21	40	40										85	[1]
22	37	37										9	[1]
23	30	30										1	[1],[2]
24	4	4										22	[1]
25	21	21										8	OLD BAG
26	22	22										35	
27	36	36										10	OLD BAG
28	25	25										26	
29	10	10										15	
30	1	1										21	OLD BAG
31	26	26										20	OLD BAG
32	34	34										35	OLD BAG
33	38	38										11	
34	9	9										1	[2]
35	8	8										20	
36	31	31										45	
Notes:	[1] Refolded Bag												
	[2] Ridge around poppet												

Table 13: Altimeter Results of Cast B

Date: 17 April 1990		Water depth based on Ship's Fathometer				3981m
					Latitude	38°13.99'N
Altimeter	CTD				Water	Altimeter
Bottom(m)	Depth(db)	gr[1]	d[1]	Depth(m)[1]	Depth(m)[2]	Delta(m)[3]
1264	2769	10	26765	2730	3994	-1
1240	2790	10	26967	2751	3991	2
1203	2830	10	27351	2790	3993	0
1166	2860	10	27639	2819	3985	8
991	3044	10	29405	2999	3991	2
889	3150	10	30422	3103	3992	1
796	3250	10	31381	3201	3997	-4
693	3350	10	32340	3299	3992	1
350	3712	10	35806	3652	4002	-9
455	3600	10	34734	3543	3997	-5
684	3367	10	32503	3315	3999	-6
836	3200	10	30902	3152	3988	4
1026	3000	10	28983	2956	3983	10
1235	2800	10	27063	2761	3996	-3
1328	2700	10	26102	2663	3991	2
1427	2600	10	25141	2565	3991	2
1532	2500	10	24179	2467	3999	-6
1804	2200	10	21292	2172	3976	17
1950	2100	10	20329	2074	4024	-31
2027	2000	10	19365	1976	4002	-9
2201	1810	10	17533	1789	3990	3
2239	1767	10	17118	1746	3985	8
2409	1600	10	15506	1582	3991	2
2537	1460	10	14154	1444	3981	12
				Average	3993	
Notes:	[1] CTD depth computed in meters from pressure in decibars using Saunders and Fofnoff's method Deep Sea Research 1976,23,109-111					
	[2] Water Depth based on Altimeter Reading and CTD Depth					
	[3] Altimeter Delta using average water depth					

found to vary from 0 to 10 cc with 10 bags having 1 cc or greater of seawater.

Conducted Cast I to 10 m with 12 new sample bags. The purpose of this cast was to investigate affect of trapped air behind the bags. The water leakage was similar to Cast H, but three bags contained 10 to 17 cc of water.
With 12 new sample bags, conducted Cast J to 1000 m to investigate water leakage through the inlet valve into the sample bag. The average leakage (values ranged from 1 to 160 cc) was higher than the previous two shallow casts. The water from the bag with the largest volume was measured for salinity. The Salinity of this water sample was 36.617 PSU versus surface water salinity of 36.551 PSU.

Monday April 22 arrive St. George, Bermuda

Evaluation Cruise, Leg 2 - Bermuda to Woods Hole

PARTICIPANTS ON LEG 2 OF TEST CRUISE:

	Individual	Affiliation	Responsibility
1	W. Jenkins	WHOI	Ch. Sci.- Water Sampler Test
2	T. Joyce	WHOI	Ch. Sci. - Oxygen Tests
3	J. Bullister	WHOI	Freon Analyses
4	D. Lott	WHOI	Sample Bag Preparation
5	C. Albro	Battelle	Water Sampler Components
6	S. McDowell	Battelle	Sample Bag Preparation
7	A. Fougere	WHOI	Control Electronics
8	C. Eck	WHOI	Control Electronics
9	G. Bond	WHOI	CTD Operation
10	C. McMurray	WHOI	CTD Data Acquisition
11	J. Kemp	WHOI	Water Sampler Deployment
12	G. Knapp	WHOI	Salinity Analyses
13	J. Jennings	OSU	Nutrient Analyses
14	R. Williams	Scripps	Oxygen Analyses
15	C. Culberson	U.Del.	Oxygen Analyses
16	F. Zembyak	Bedford	Oxygen Analyses

SEQUENCE OF EVENTS:

Saturday 0900 AST April 28. Depart St. George, Bermuda

Thirty eight new valve bodies were hand-carried from Battelle; each had magnet rings potted-in as compared to those used on the first leg which were epoxied into the valve body. Half-size bags were added on new valve bodies. Tape was applied to entire back of valve body. A vacuum was drawn on assembled bags to determine whether valves and bag seams were tight. Initial pass/fail test was based upon reaching a vacuum of <25 torr after 1 minute of pumping. Bags were rigid when evacuated, but after awhile they relaxed, indicating that air was passing the gasket and entering the bags.

Thirty six bags were installed in the sampler and a leakage test was performed during Cast 'K' by lowering the sampler to a depth of ~15 m. After ~5 minutes without pumping, the sampler was recovered and bags were removed. All bags were opened and leakage water was collected with a syringe and measured to 0.1 ml. Volume of leakage ranged from 0.5 to 12.0 ml. All results were entered into a data base and a high correlation was observed between leakage volume and the vacuum obtained during pre-cast vacuum pumping for 1 minute (e.g., low leakage was observed for bags that could achieve a low

pressure). Leakage was <2 ml for bags that could be pumped to <12 torr in 1 minute. (See Appendix C).

Therefore, the bag assembly technique was modified to improve the sealing of the bags to the valve body; the result was that most bags could be pumped to a vacuum of <5 torr, and therefore should leak less than 2 ml.

<u>Sunday</u> April 29.

Thirty six bags were prepared for the next cast. All valve/poppets were initially tested to ensure that the poppet gasket could be pumped to <1 torr in 2.5 minutes. Each bag was evacuated and a pass/fail threshold of <12 torr was used to select bags for the next cast. Again, the bags were observed to lose their vacuum prior to being installed within the drawers.

The second leakage test (Cast L - Station OC29D014) was performed by lowering the sampler to a depth of 5000 m, waiting for 5 minutes without pumping, then returning to the surface.

All bags were opened and leakage water was collected with a syringe and measured to 0.1 ml. Volume of leakage ranged from 0.05 to 6.0 ml and is listed in Table 14. Some of the leakage samples were analyzed for nutrients, and the silicate concentrations indicated that the water was entering at depth rather than at the surface. Again, a high correlation was observed between leakage volume and the minimum pressure that the bag could be pumped during 1 minute (Table 14). Leakage was <2 ml for bags pumped to less than 5 torr. The rate of leakage as a function of vacuum was much higher than the first, shallow test, presumably due to the increased pressure and/or emersion time.

When making up the next set of bags, a pass/fail limit of 5 torr was used to select a good set of bags.

The altimeter worked well on this cast. With a blanking interval of 200 msec, reliable height-off-the-bottom information could be achieved 1500 m off the bottom. When the altimeter's blanking interval was reduced near the bottom, reliable information was received on each interrogation. A comparison of CTD pressure, altimeter heights and differences is given in Table 15.

Fig. 16 shows the unedited, processed, summary plots from Cast L - Station OD29D014. There is a mixed layer and sharp thermo-, halo- and pycnocline about 800 meters deep. The potential density is nearly constant from 4000 to 5000 meters, with a hint of unstable water near the bottom. A blowup of the 200 m section just below 2000 meters depth (Fig. 17) shows similar velocity dependent structure as was seen in Fig. 15. Note that the cool, fresh layer seen just below 2120 meters is almost absent in the sigma-theta profile, but possibly indicative of an unstable event. There is a large data gap between 625 and 810 meters. The decrease in lowering speed at the surface, just below 4000 meters and near the bottom is evident in the plot of number of points averaged.

<u>Monday</u> April 30.

Ten bags were prepared for the next lowering, a pumping test. Six drawers were to be pumped; 4 drawers were for leakage tests.

On Cast M (Station 17) the sampler was lowered to 926 m and 6 drawers were pumped. Only one water sample was obtained from the drawers that were pumped. The four non-pumped bags were opened and leakage water was collected with a syringe and measured to 0.1 ml. The volume of leakage ranged from 1.2 to 6.5 ml. Only the surface water sample obtained water. Large cracks were

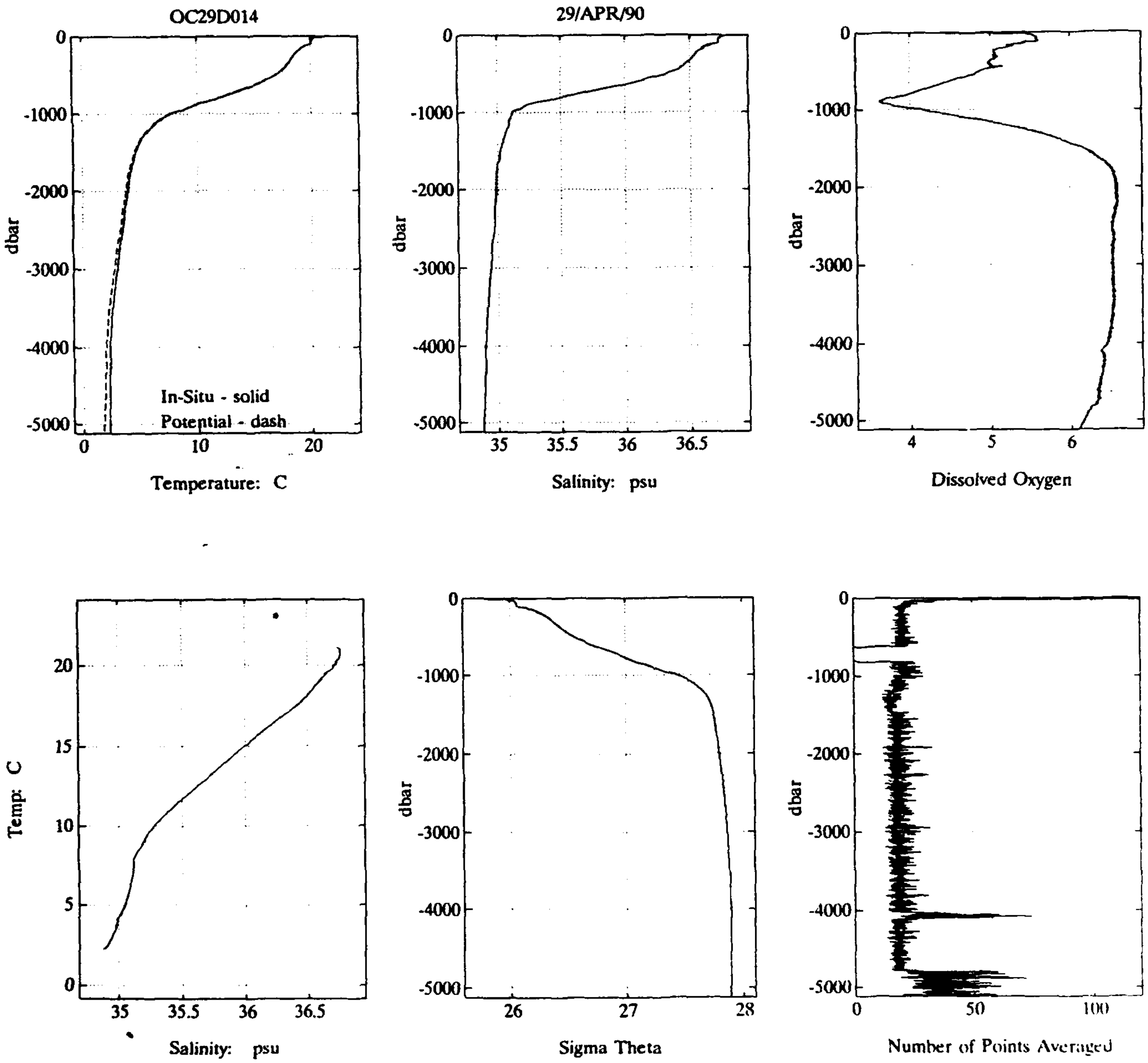


Figure 16: 200 Meter Profile of Station OC29D002, Fig. 14

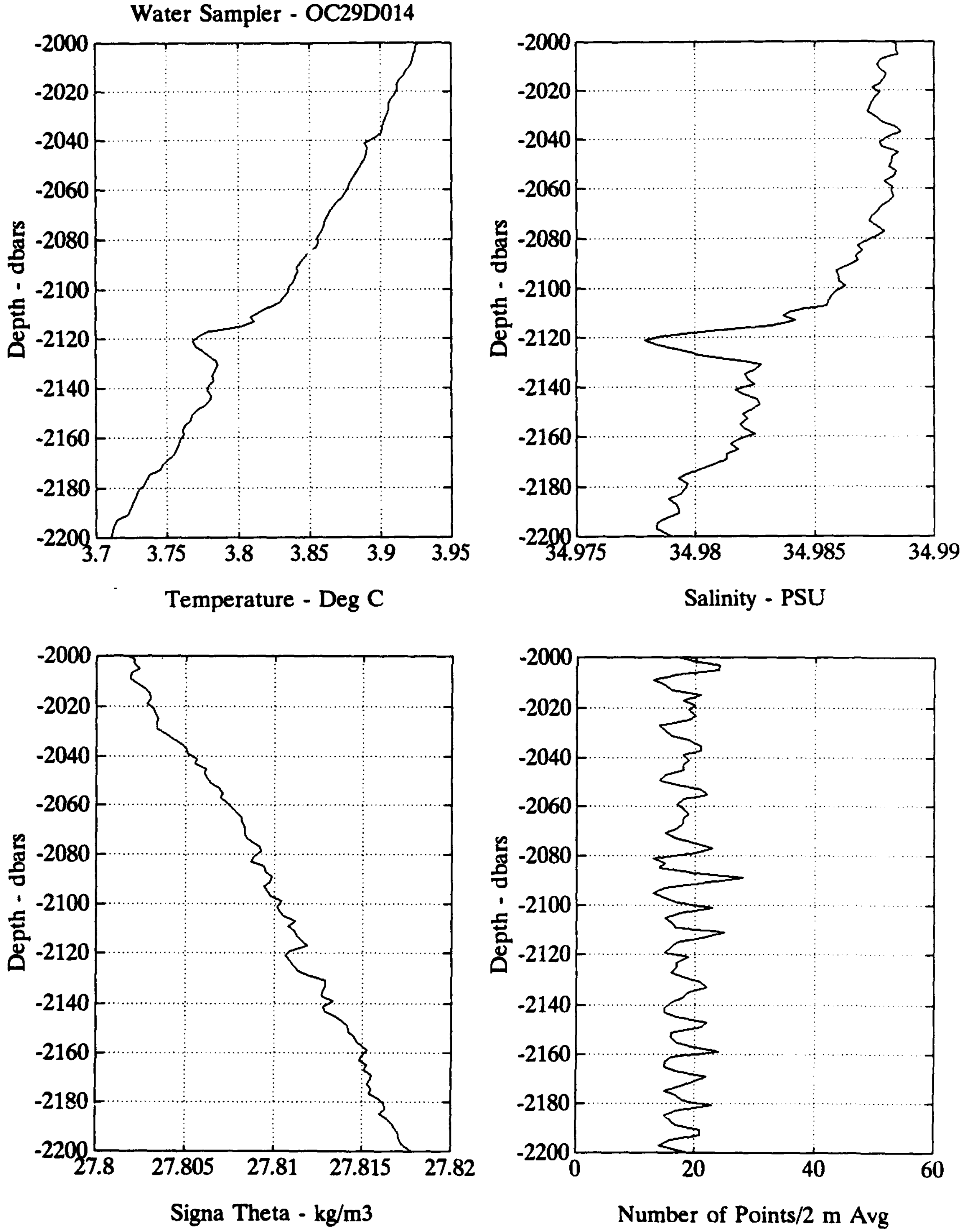


Figure 17: Detailed 200 meter profile of Station OC29D014, Fig. 16

discovered in each of the drawers pumped, indicating that the pump was drawing hard, but the poppet valves did not open.

For Cast N (Station 18) the 5 drawers that failed to fill in the last cast were reinstalled and drawers was pumped at 100 m intervals. It was assumed that the void space behind the poppet, between the gasket and the end of the poppet, was causing a pressure differential between it and the ambient (high) pressure such that the poppet could not be opened by the ~7 psi cracking pressure induced by the pump.

Bags were prepared for another lowering. As a test on two poppets, large-diameter neoprene gaskets were fabricated and attached to the outer diameter of the poppets. Four other bags were made up with no gasket on the poppets.

For Cast O, the sampler was lowered to a depth of 5000 m and 7 drawers were pumped between 5000 and 4058 m. Upon recovery of the sampler, the drawers with the gasket on the outer edge of the poppet collected 6.4 and 4.8 liter samples, whereas, the other drawers with conventional, small-diameter poppet gaskets and those having no poppet gaskets did not collect a water sample. It was concluded that the void space behind the poppets (either with the original gaskets or without gaskets) prevented the poppets from opening. Furthermore, during past lowerings and pressure tests, when water samples were collected successfully, this must have occurred after a significant volume of water had leaked into the bags, thus eliminating the low-pressure void space behind the poppet.

Nine bags (including 5 that failed to fill) were opened and leakage water was collected with a syringe and measured to 0.1 ml. Volume of leakage ranged from 0.5 to 100.0 ml.

An on-deck pressure cracking test was conducted with a bag having an original gasket and a vacuum of 1.1 torr. A pressure of 15 psi was applied to the valve, but it was insufficient to crack the valve because of the vacuum. With no vacuum, this valve had a cracking pressure of ~6 psi.

The altimeter provided reliable height-off-the-bottom information was obtained to ranges of 1500 m.

<u>Tuesday</u> May 1.

Twenty bags were prepared for Cast P, Station 22. Ten bags were to be pumped; the remaining ten were for leakage testing.

The inner gasket of all poppets was removed and a large-diameter gasket was made of neoprene and attached to the outer edge of each poppet with two-sided tape. All bags were evacuated to <10 torr to ensure that bags had good seals. The bags were back filled to 1/2 atm with nitrogen. Two bags were heat-treated for freon decontamination.

The sampler was lowered to 3500 m and 3 samples were pumped. Single samples were taken at depths of 3000, 2500, 2000, 1500, 1000, 500, and 20 m. Full, 7-liter samples were acquired by 9 of the 10 drawers pumped. Upon inspection of the inside of the failed bag, it was determined that the bag had been inadvertently heat-sealed in many places during the heat-treating process. Apparently, the oven temperature was much greater than the recommended 60°C (140 °F).

All 10 bags for the leakage test were opened and leakage water was collected with a syringe and measured to 0.1 ml. Volume of leakage ranged from 6.0 to 136.0 ml. Nutrient analyses of the leakage water indicated that water entered the bags at some intermediate depth.

Table 14: Cruise 219 NSF Water Sampler Cast Log, Cast L

Cruise 219 NSF Water Sampler Cast Log													
Cast:	L				Date:	29-Apr-90			Time in:	not recorded			
Battery Set Used:				not recorded									
			Time in	Pumping Time		Cast	UWU	Water	Battery		Cracking	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Vacuum	Pressure	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)	(torr)[1]	(psi)[2]	(ml)[3]	Remarks
1	83						5000			4.40		5.7	
2	59						5000			1.32		1.2	
3	63						5000			3.58		1.6	
4	56						5000			8.90		5.0	
5	87						5000			5.50		4.2	
6	66						5000			4.25		4.8	
7	57						5000			2.93		2.1	
8	64						5000			7.25		4.7	
9	84						5000			3.26			not recorded
10	70						5000			2.60		0.9	
11	58						5000			7.95		6.0	
12	74						5000			7.90		3.4	
13	77						5000			3.16		1.2	
14	53						5000			9.90		5.6	
15	79						5000			3.42		1.8	
16	52						5000			1.38		0.1	
17	71						5000			4.47		2.4	
18	65						5000			3.30		2.4	
19	62						5000			2.10		0.4	
20	61						5000			6.00		5.5	
21	50						5000			6.15		4.6	
22	80						5000			5.47		0.9	
23	81						5000			2.09		0.1	
24	76						5000			5.95		3.4	
25	78						5000			6.03		5.6	
26	75						5000			5.95		3.0	
27	69						5000			4.52		2.6	
28	72						5000			1.68		0.2	
29	55						5000			1.69		0.2	
30	85						5000			1.87		0.2	
31	51						5000			2.82		1.0	
32	88						5000			4.97		4.2	
33	73						5000			3.60		1.2	
34	86						5000			6.35		4.4	
35	67						5000			2.56		0.5	
36	68						5000			2.64		1.5	
Notes:	[1] Vacuum level bag was evacuated												
	[2] Cracking is pressure (psi) to leak water												
	[3] Volume of water found in bags												

Table 15: Altimeter Results of Cast L

Date: 29 April 1990			Water depth based on Ship's Fathometer			5111m
					Latitude	33°49.32'N
Altimeter	CTD				Water	Altimeter
Bottom(m)	Depth(db)	gr[1]	d[1]	Depth(m)[1]	Depth(m)[2]	delta(m)[3]
1099	3910	10	37704	3847	4946	105
940	4138	10	39874	4068	5009	42
946	4358	10	41974	4283	5229	-178
811	4480	10	43142	4402	5213	-162
528	4589	10	44184	4508	5036	15
467	4657	10	44828	4574	5041	10
394	4725	10	45474	4639	5034	17
359	4765	10	45858	4679	5038	13
308	4822	10	46400	4734	5041	9
243	4887	10	47018	4797	5040	11
218	4921	10	47345	4830	5048	3
164	4967	10	47782	4875	5039	12
85	5053	10	48600	4958	5044	7
110	5028	10	48364	4934	5045	6
234	4903	10	47176	4813	5047	4
322	4819	10	46375	4731	5053	-2
431	4697	10	45211	4613	5043	8
485	4647	10	44736	4564	5049	2
527	4597	10	44254	4515	5042	9
620	4504	10	43373	4425	5046	5
714	4400	10	42376	4324	5038	13
849	4292	10	41345	4218	5067	-17
871	4245	10	40901	4173	5044	7
942	4166	10	40147	4096	5038	13
1116	3979	10	38356	3914	5030	21
1443	3659	10	35301	3602	5045	5
1513	3580	10	34546	3525	5038	13
1629	3463	10	33419	3410	5039	12
1714	3371	10	32537	3320	5034	16
1823	3265	10	31528	3217	5040	11
1938	3150	10	30420	3104	5042	9
2110	2976	10	28753	2934	5044	7
2356	2729	10	26378	2692	5048	3
2505	2574	10	24894	2540	5045	5
2617	2464	10	23831	2432	5049	2
2734	2352	10	22755	2322	5056	-5
2943	2141	10	20723	2115	5058	-7
3051	2050	10	19851	2026	5077	-26
3131	1958	10	18960	1935	5066	-15
				Average	5051	
Notes:	[1] CTD depth computed in meters from pressure in decibars using Saunders and Fofnoff's method Deep Sea Research 1976,23,109-111					
	[2] Water Depth based on Altimeter Reading and CTD Depth					
	[3] Altimeter Delta using average water depth					

<u>Wednesday</u> May 2. Enroute to Woods Hole

Discussed results of Cast P. A decision was made that additional lowerings would not be useful; additional tests are needed onshore before sea trials.

On-deck tests were conducted to determine the cracking pressure of the valve with the gasket on the outer diameter of the poppet which was found to be less than 1 psi. Repeated tests were conducted with a bag that had been evacuated to 2 torr; no significant increase in cracking pressure due to a vacuum on the bag and poppet was observed.

<u>Thursday</u> 0800 EDT May 3. Arrive at Woods Hole

Testing and Evaluation Results

Below is a list of the significant results and/or conclusions based on the evaluation cruise testing:

Underwater Unit

In rougher seas, the air trapped in the underwater unit presented a potential problem as was witnessed during the launch for Cast H.

The tilt sensors indicated that the sampler had a preferred orientation (axis of tilt) and that tilt reaches 30 degrees under moderate sea states and lowering rates. Can the symmetry, ballast, and/or BG be changed to reduce tilt during typical lowering rates?

Peak wire tensions were very high and oscillatory during lowerings in moderate sea states. Is the combination of low drag and high inertial mass a problem? Will a motion compensator on the winch be mandatory for deep casts, even in mild sea states?

The tension sensor on the underwater unit was inoperable. More information on wire tension is needed to model the response of the underwater unit under a variety of sea states.

Water Acquisition System

The rotary valve successfully accessed all 36 sample drawers during all but two deep casts without a single positioning error. It was determine that at one position of the rotation the rotary valve stuck at depths greater than 3600 m. By moving to a more shallow depth, the rotary valve could be moved past the sticking point and continue to operate. It is believe that a slight mis-alignment between the rotary valve and fixed tube was causing the problem.

The flowmeter is not functioning as expected. Can it be calibrated, or does it need to be relocated to operate properly? Can it be replaced by a differntial pressure sensor?

Better adhesives are needed for attaching bags to valve bodies so that bags will not separate from the valve during evacuation.

Based on the broken drawers and that some of the sample bags were full, it was concluded that the pumping system was providing more than 7 psi differential pressure.

The magnetically operated inlet valve allowed air and water to leak into the sample bags prior to (and possibly after) the collection of a sample in quantities sufficient to destroy or at least affect sample integrity. Fig. 18 shows the relationship of evacuation pressure and sampling depth to leakage volume. In general, leakage volume reduces with evacuation pressure and increases with sampling depth. The inlet valve also did not open reliably.

CTD System

A WHOI-owned EG&G/NBIS Mark III-B CTD was used for the test lowerings. This unit was modified to accept data from a tension cell, a compass (spin detector), and a 2 axis tilt sensor, all of which were mounted in the underwater unit. Visual inspection indicated that the quality of the CTD data string was not degraded by the altimeter nor activation of the water sampler control unit.

Communication System

The communication system for the water sampler worked well with few, if any, errors in the two-way communication. Activation of the rotary valve, monitoring of the batteries, interfacing with the CTD data stream, and communication with the altimeter were all operable.

Power System

The 48-volt battery pack within the underwater unit was fully capable of driving the water sampler components and the altimeter. Fig. 19 shows the reduction in voltage as a function of pumping time.

Altimeter

The communication interface to the altimeter was operational for changing all of the altimeter's settings. Then properly adjusted, the altimeter successfully acquired the bottom. Fig. 20 shows the altimeter reading versus calculated height based on the ship's fathometer minus CTD depth. Fig. 21 shows the height delta as a function of altimeter reading.

Preparation of Sample Bags

For the evaluation cruise, the preparation of the sample bags was time-consuming and labor intensive. Before the cruise, 400 bags were partly assembled by heat sealing three edges of two sheets and cutting a 2" diameter hole in one sheet. Also, for the cruise, 78 inlet valve assemblies were fabricated. The at-sea refurbishment procedures were as follows:

- Remove bag material from valve body.
- Remove any tape residue from valve body.
- Retape valve body.
- Attach new bag to valve body.
- Insert poppet valve inside new bag.
- Attach stops to poppet valve.
- Heat seal the open end of the new bag.
- Evacuate bag to test quality.
- Install 2 bags into purge system.
- Conduct 2 purge cycles (2 h).

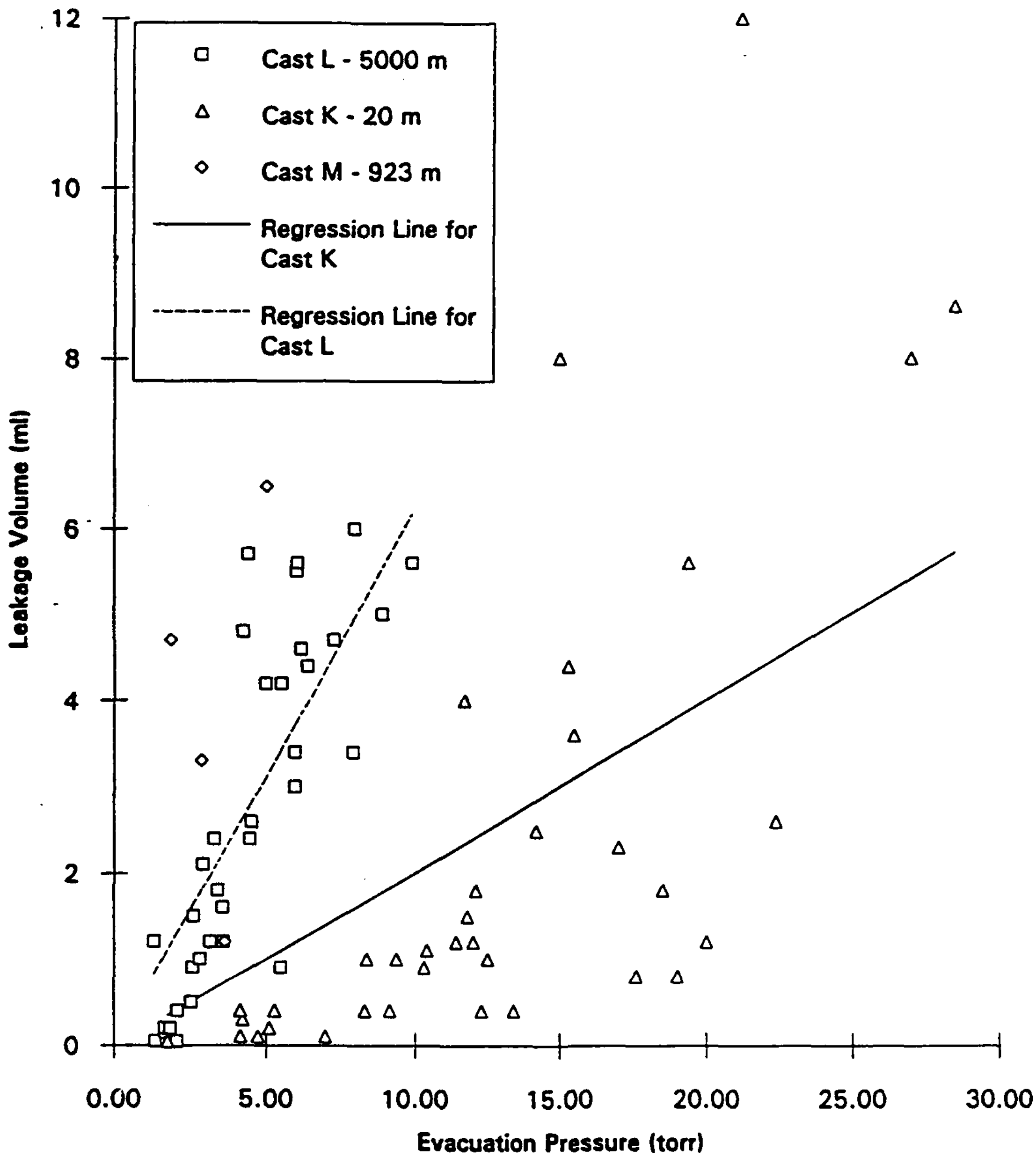


Figure 18: Relationship of Evacuation Pressure to Water Leakage

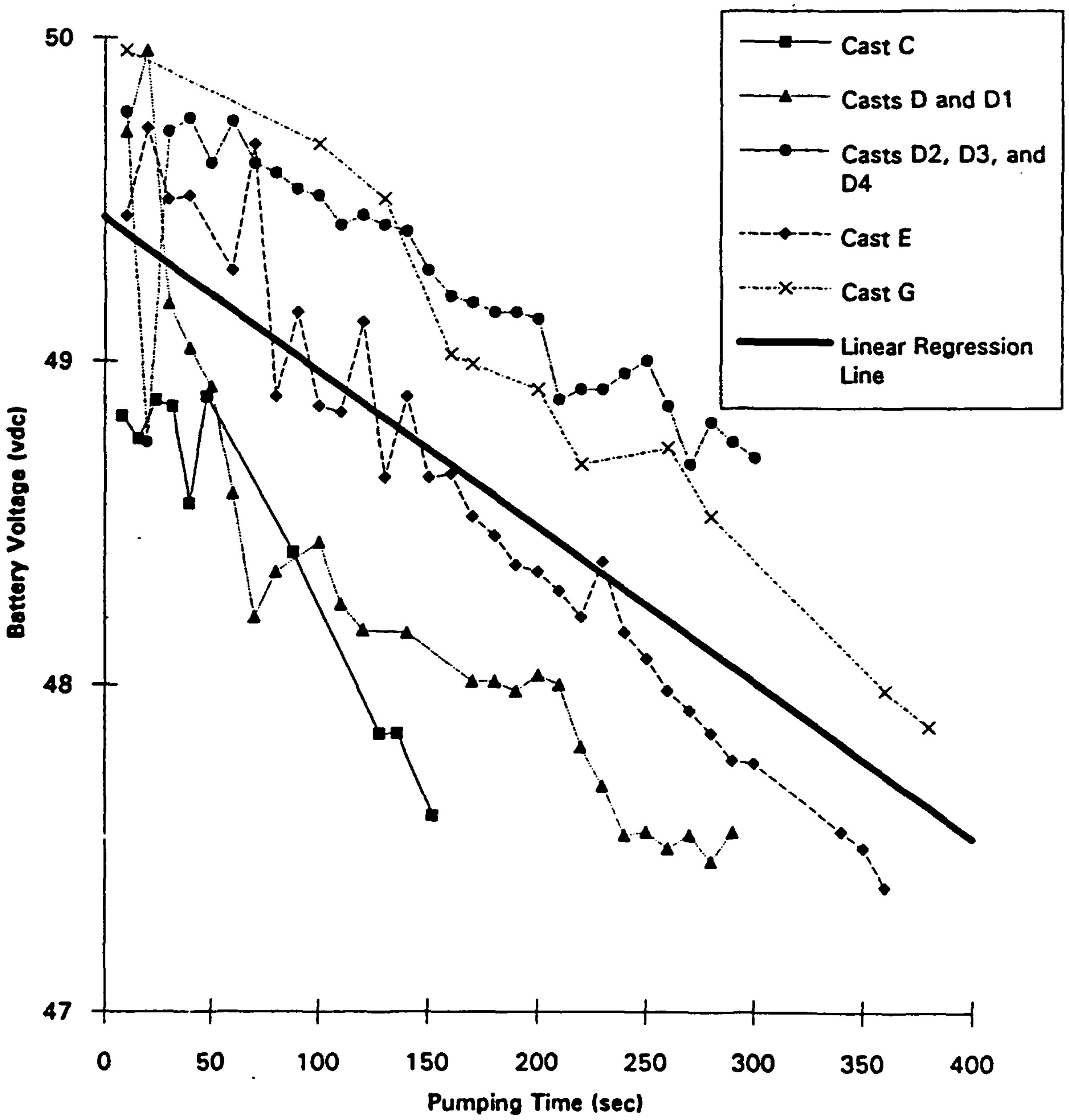


Figure 19: Reduction in Voltage as a Function of Pumping Time

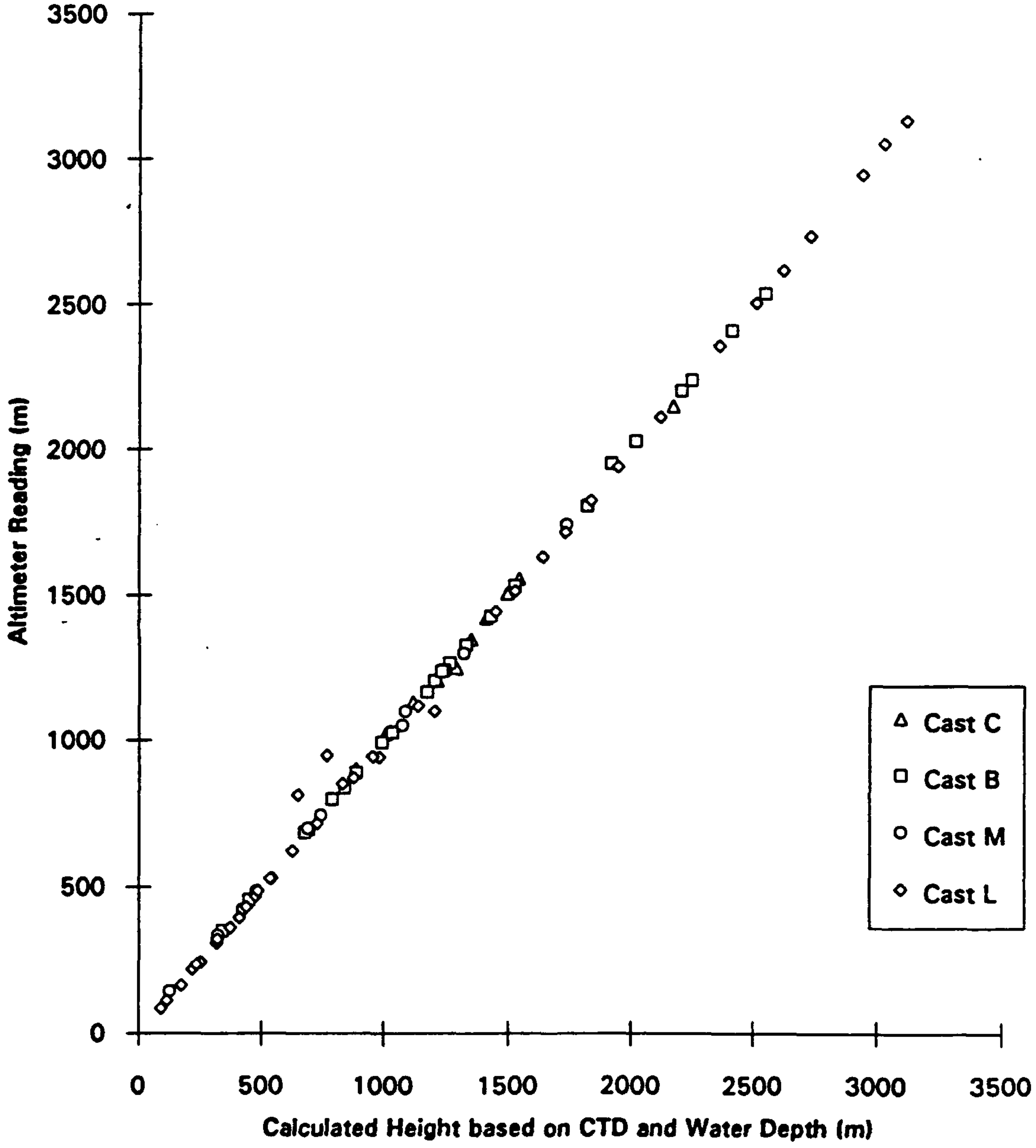


Figure 20: Altimeter Reading Versus Calculated Height

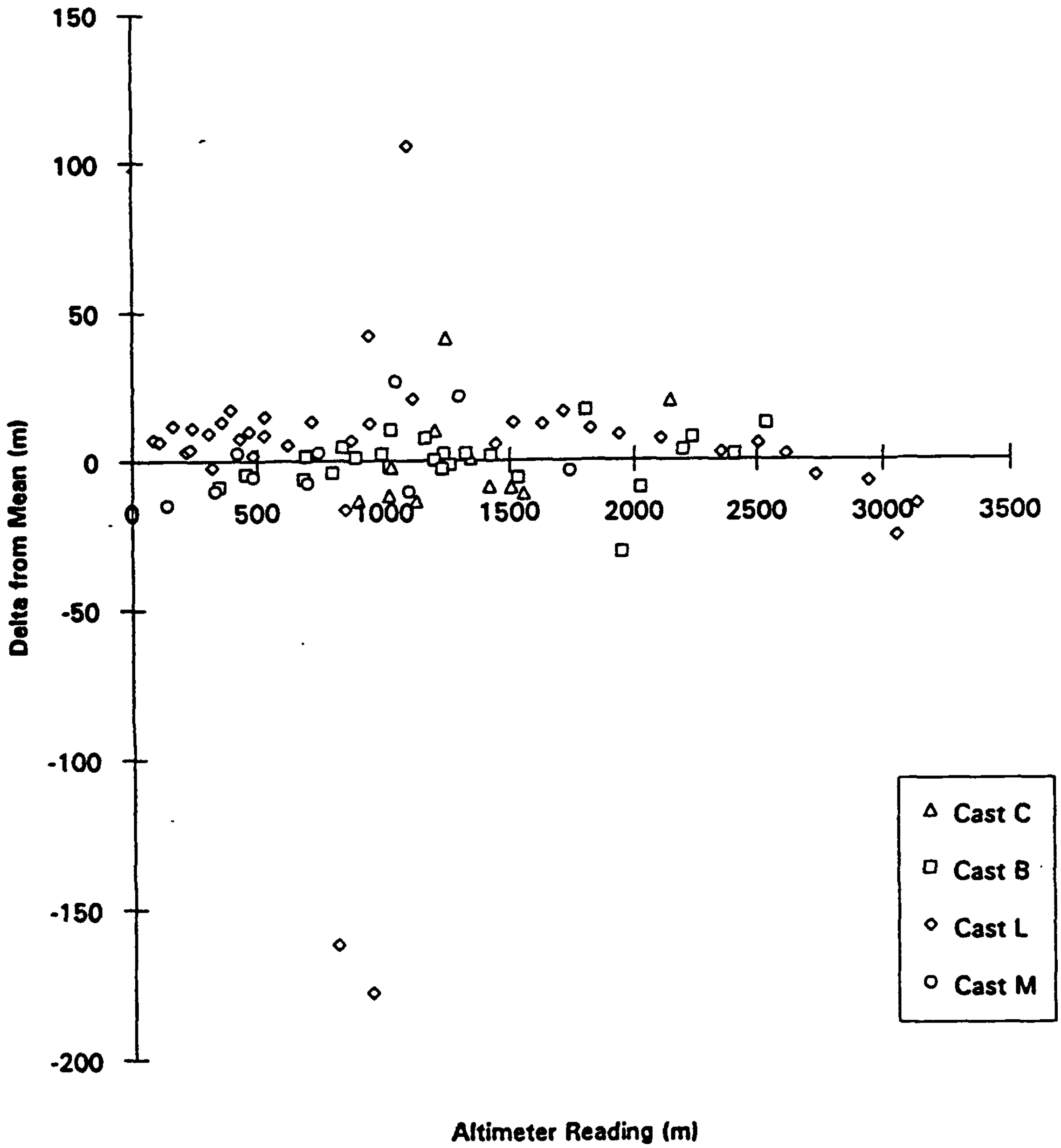


Figure 21: Delta Altimeter Reading from the Calculated Mean Height

- Remove 2 bags from purge system.
- Install a second set of 2 bags into purge system.
- Conduct 2 purge cycles (2 h).
- Fabricate other 32 bags in parallel with purged bags.
- Fold and install each bag into drawer.
- Install 36 drawers into Underwater Unit.

The proposed procedures for production sample bags would be as follows:

- Install 36 factory-fabricated bags with valve into purge system.
- Conduct 2 purge cycles (2 h).
- Fold and install each bag into a drawer.
- Install 36 drawers into Underwater Unit.

As can be seen from the two descriptions, the preparations during the evaluation cruise doesn't give a realistic indication of the effort required.

General Evaluation

The results of the evaluation cruise showed that the prototype performed well in the electronic and most mechanical areas. However, water-acquisition inlet-valve operations and flight stability were found to negatively impact the scientific measurements. The magnetically operated inlet valve allowed air and water to leak into the sample bags prior to (and possibly after) the collection of a sample in quantities sufficient to destroy or at least affect sample integrity. The inlet valve also did not open reliably.

Flight Stability

Some kiting off of a vertical flight path was observed during the terminal velocity test; the extra lines attached and the presence of several dents and openings in the sheet metal skin were thought to be the cause.

The prototype unit displayed a tendency to oscillate and kite off of a vertical flight path at sea, during both lowering and recovery. A number of possible causes have been identified and solutions have been suggested but cannot be implemented without further funding.

Static stability is achieved by the weight and buoyancy distribution on the vertical axis. The position of the heavy CTD case, the CTD guard, and the other pressure cases causes the horizontal center of gravity and center of buoyancy to be slightly off the central axis. This can be corrected with ballast weights in the proper location.

The protruding CTD guard causes an unbalanced drag force which disturbs the flight stability. A vertical radial fin placed between the two sensor arms would provide less flow disturbance, less drag, and protect the sensors at least as well. Two similar fins with slightly more drag to balance the sensor arms would be placed at 120 degrees around the circumference.

It is unclear how much the action of the pump and off center drawer opening suction deflects the body from vertical flight.

Published literature suggests a body aspect ratio of greater than 6:1 is required for flight stability. The largest aspect ratio that is practical for this application for ease of access to samples and safe handling is 38:1. Tests of similar bodies conducted at WHOI and at the Naval Hydroballistic Facility at White Oaks, Maryland, has shown that this body would benefit from the addition of an afterbody drag element. The proposed modification calls

for the addition of an annular ring protruding from the upper shroud, as an axisymetric drag element for the downcast direction. The sampler follows the cable tension vector on the upcast. A horizontal fiber fringe around the circumference of the upper and lower shrouds might also be effective. Only full scale testing of several options will tell what combination of modifications are necessary and most effective.

NEW DONUT SEAL BAG DESIGN AND TESTING

New Seal Concept

After the evaluation cruise, poppet valve designs were considered that could meet leakage limitations of 0.14cc of air and 1.0 cc of water per 7 liters. It was concluded that an alternate approach was needed. After several brainstorming sessions, a new approach was identified. This new approach uses a bag that is completely flat with all the edges heat sealed. The bags can be manufactured in a clean, nitrogen gas environment and sealed within a package until they are installed in the Water Sampler, thus assuring chemically clean bags. Each bag will then be attached to the inside of its drawer at the inlet opening. The bag will remain sealed until the pressure differential created by the pump opens the bag by separating the two sheets around the peelable donut seal (Fig. 22). A simple closure valve would then trap the water sample in the bag and prevent external contamination. This new approach offers several advantages:

- eliminates at-sea evacuation/purging of sample bags, thus saving valuable at-sea time
- eliminates air leakage on deck prior to deployment
- eliminates water leakage until sample collection is initiated
- reduces at-sea storage requirements
- eliminates the poppet valve inside the sample bag
- keeps most of the existing Water Sampler design features intact
- reduces the cost per sample container, since only two sheets are required per bag.

Before continuing with the water-sampler development, it was necessary to demonstrate that fabricated bags would leak less than 1 cc of water and still be systematically and reliably opened and filled at all depths between the surface and 9000 psi (6000 m).

Before testing could start, it was necessary to design, procure parts, and fabricate a donut sealer module to attach to a commercial heat sealer. The module is an aluminum donut bar (2" ID x 2.5" OD) that is pressed against a flat rubber surface. The donut bar is on a pivot arm operated by air cylinders. The flat rubber surface is attached to the fixed part of the sealer. Embedded into the donut bar are two 1/4" diameter cartridge heaters that are connected to a temperature controller. A thermocouple is bonded to the donut bar and is connected to the temperature controller. This donut heat sealer was used to seal the circle cutout in one sheet of the bag or coupon to another sheet. The commercial heat sealer was used to control the squeezing pressure and dwell time (length of time pressure and heat are applied).

New Seal Testing

Three tests setups were used in conducting tests - static cracking pressure setup, dynamic cracking pressure setup, and high ambient pressure opening setup. These test setups are described below.

Static Cracking Pressure Setup

To determine the static cracking pressure, the setup illustrated in Fig. 23 was used. Static cracking pressure is define as the point when the

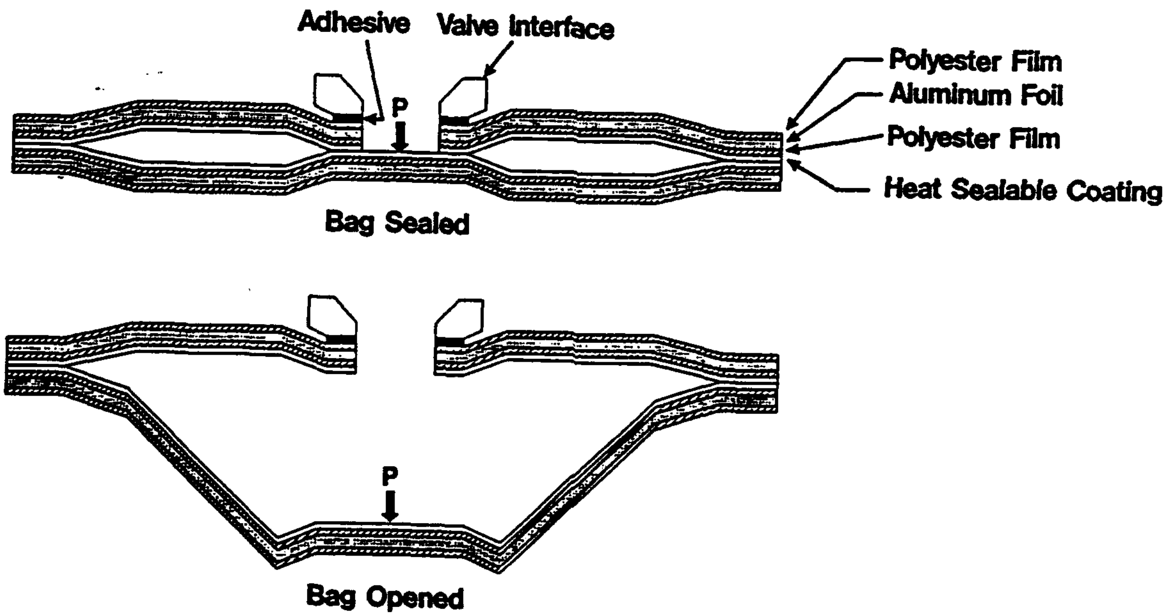


Figure 22: Donut Seal Concept

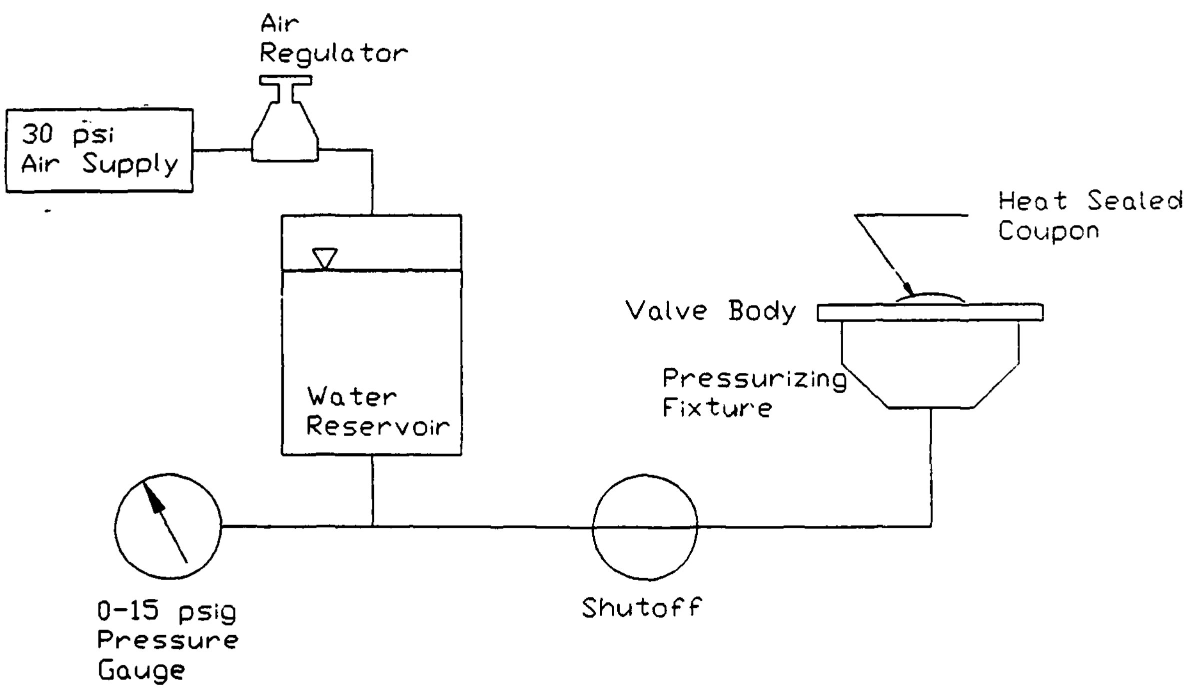


Figure 23: Test Setup for Determining "Static" Cracking Pressure

slowly increasing pressure causes water to leak by the donut heat seal. The following procedures was used:

1. Make test coupon consisting of two sheets about 5"x7". One sheet has a 1.75" diameter hole and is heat sealed to the other sheet.
2. Attach the coupon to the valve body using double sided tape.
3. With pressure at 0 psig and shutoff open, clamp pressurizing fixture to valve body face.
4. Using air regulator, slowly increase pressure until water leaks by heat seal or until tape lifts. Then close shutoff.
5. Record pressure which is the static cracking pressure.
6. Reduce pressure using air regulator.

Dynamic Cracking Pressure Setup

The test setup for determining the dynamic cracking pressure is shown in Fig. 24. Dynamic cracking pressure is define as the pressure required to separate the donut seal using the water acquisition pumping system. The components used in the test setup includes drawer, Rotary valve mockup, inlet pump piping, the centrifugal pump used in the Underwater unit, an AC electric motor to drive the pump, pump outlet plumbing with paddlewheel flowmeter similar to the one use during the April evaluation cruise, pressure transducer attached to drawer lid. The pressure transducer and flowmeter were connected to an analog to digital interface in a MS-DOS computer. The following test procedure was used to determine dynamic cracking pressure, time to cracking pressure, time for valve to be fully open, and time to fill the bag:

1. Make coupon or bag
2. Attach coupon or bag using double sided tape
3. Pretest to 5 psi using "Static" cracking pressure test setup.
4. Install valve body into drawer
5. Install drawer lid which has pressure transducer
6. Start computer data acquisition, recording pressure and flow rate at approximately 400 Hz
7. Operate pump 5 to 15 seconds.
8. Save data to file.
9. Software program displays data, calculates cracking pressure, time to cracking pressure
10. If using a bag, it also calculated time for valve to fully open, and time to fill bag.

Fig. 25 shows six examples of test results using the dynamic cracking pressure test setup.

High Ambient Pressure Opening Test Setup

For high ambient pressure (9000 psi) opening tests, a test fixture holding a sampler drawer with sample bag, mockup of the rotary valve, pump, motor, battery pack, and controller was inserted into the WHOI high pressure tank. Using a electrical feed through, the pump was operated with the control software used during the evaluation cruise.

Conclusions

From July 1990 through March 1991, Battelle and WHOI conducted tests with more than 600 coupons and bags to demonstrate that the Donut Seal Concept can meet the above two criteria. The following subsections, start with a conclusion followed with supporting documentation.

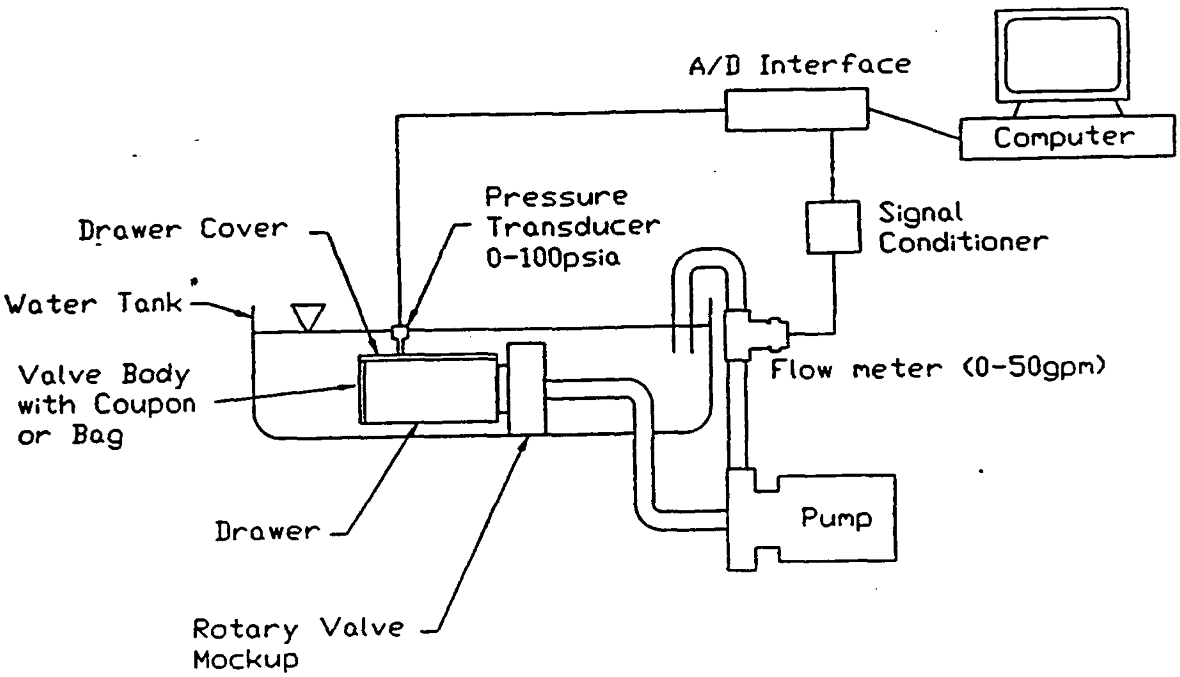
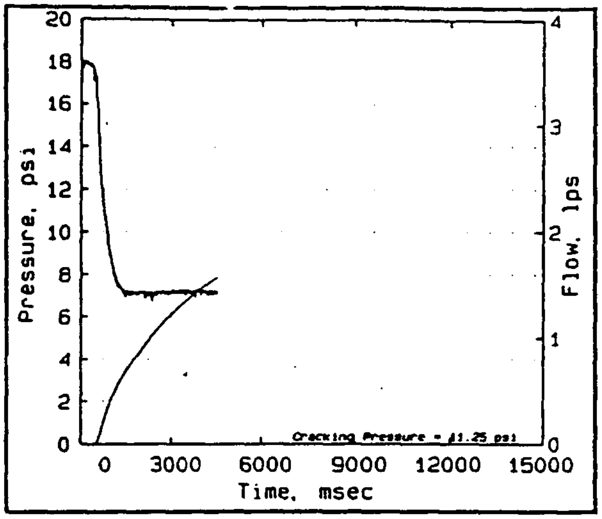
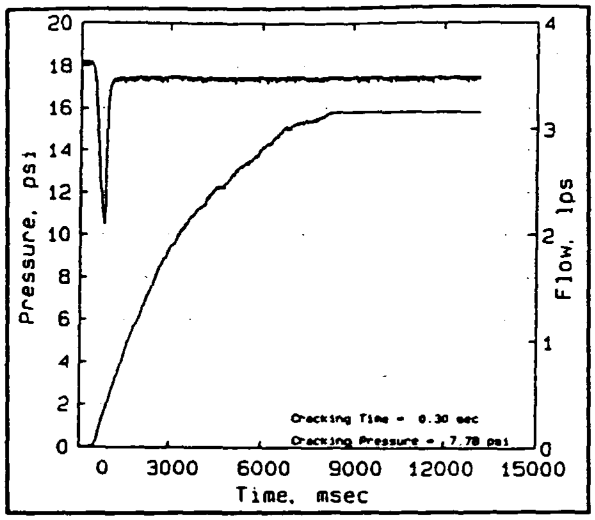


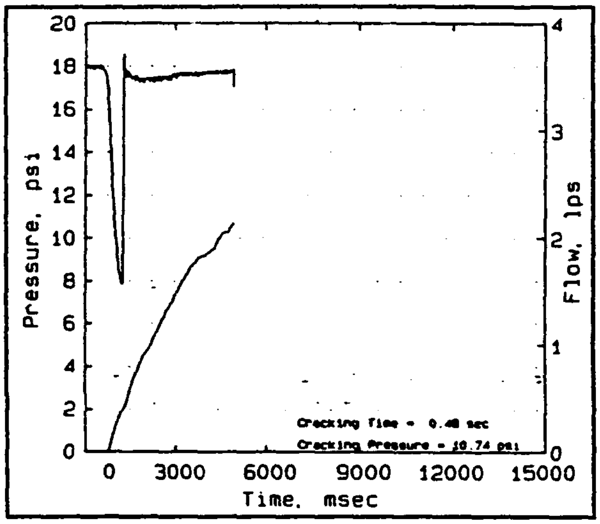
Figure 24: Test Setup for Determining "Dynamic" Cracking Pressure



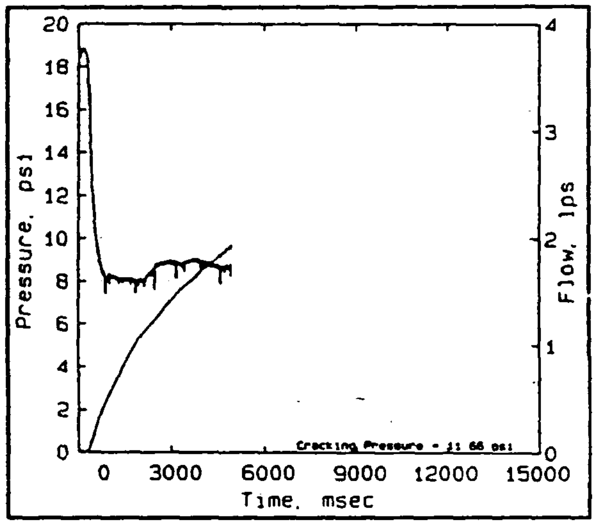
Coupon failed to open.



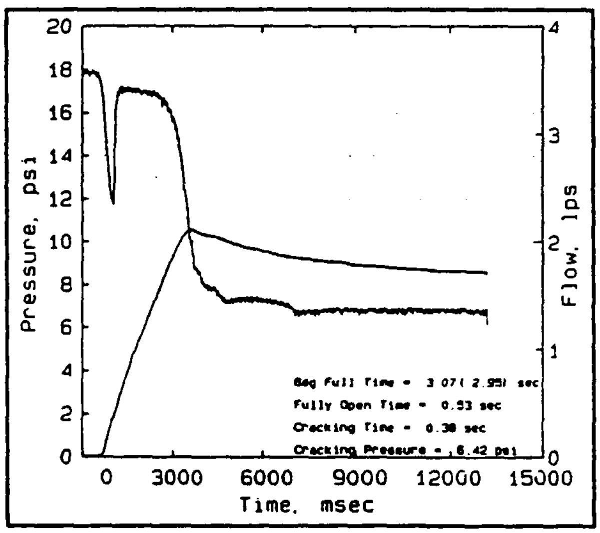
Coupon successfully opened.



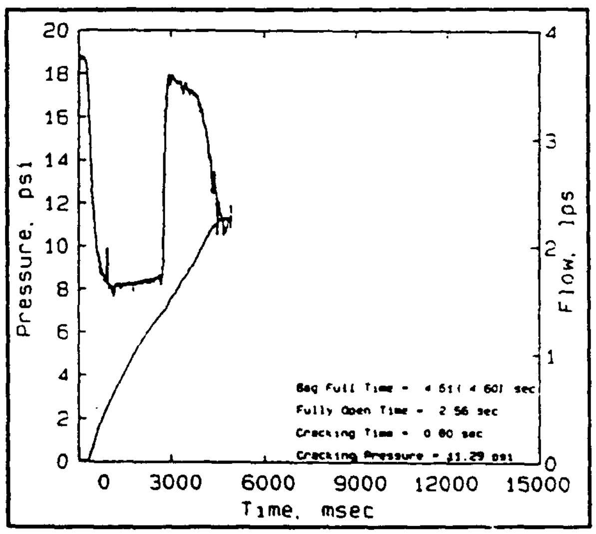
Coupon Failed to Open, Lid Popped off



Bag failed to open



Bag successfully opened and filled.



Bag successfully opened and filled.

Figure 25: Examples of Dynamic Cracking Pressure Test Setup Results

Sample bags can be opened and filled at low ambient pressure (1 atmosphere) and room temperature (10-20°C).

Over several months, 125 full size bags were dynamical tested at atmospheric pressure and room temperature (10-20°C). One hundred and nine of these bags opened and filled with the resulting cracking pressure varying from 3.67 psi to 11.48. The higher ranges were achieved by stiffening the drawer to prevent the lid from being popped at pressures higher than 10 psi.

Sample bags can be fabricated that leak less than 1 cc after being subjected to high ambient pressure and room temperature.

To determine water leakage when subjected to high ambient pressure the following test procedures were used:

1. Full size bags were made with the donut heat sealer settings adjusted to provide 6-9 psi dynamic cracking pressure.
2. Each bag was numbered and weighed on a scale with a resolution of 0.01 g.
3. All bags were submerged in water in the WHOI high pressure test tank.
4. The bags were subjected to a 4-h pressure cycle to 9000 psi and back.
5. Each bag was carefully wiped dry with paper towels.
6. Each bag was weighed.

For the last batch of 20 bags, the worst case leakage was only 0.12 g.

Bags can be fabricated that leak less than 1 cc, even after two pressure cycles to 9000 psi.

Sample bags can be opened at low ambient pressure and cold temperature (<3 °C).

Twenty coupons were dynamically tested at atmospheric pressure and in cold water (<3°C). All the coupons opened with the cracking pressure ranging from 7.29 to 8.95 psi.

Thirty full size bags were dynamically tested at atmospheric pressure and in cold water (ice batch, 0°C). When subjected to the 7-13 psi pressure differential created by the pump, 26 of the bags were opened and rapidly (5 seconds or less) filled.

Sample bags can be opened and filled at high ambient pressure and room temperature.

Table 16: Bag Leakage After Pressure Cycling

Bag Id	Leakage after first pressure cycle (g)	Leakage after second pressure cycle (g)	Total Leakage after two pressure cycles (g)
B-6	0.29	0.22	0.55
B-3	0.52	0.44	0.56
C-6	0.23	0.05	0.28
C-14	0.34	0.12	0.46
C-1	0.22	0.07	0.29

In October 1990, twelve full size bags were dynamically pumped at 9,000 psi in the WHOI tank. Of these twelve, two did not open, one opened but did not fill (only 1 L), the other nine filled completely and with only 5 seconds of pumping time.

In early 1991, twenty bags were all successfully opened at high ambient pressure. Two bags were not full. All others contained at least 6 L.

The shiny surface that is exposed when peeling the donut seal is polyester film not aluminum.

To demonstrate that the shiny surface that is exposed when peeling the donut seal is polyester film not aluminum the following test procedures were conducted.

1. Taking a coupon that was used and had a lot of exposed shiny surface, concentrated HydroChloridic Acid (HCL) was applied to the surface.
2. No reaction was observe even when viewing with a 25 power scope.
3. Dried off the HCL.
4. Applied Dimethyl Chloride (DCM).
5. Observed a strong reaction.
6. Allowed the reaction to occur for about 1 minute.
7. Dried off the DCM.
8. Applied several drops of HCL. Under 25 power could see a very mild reaction in a couple of spots.
9. Dried off the HCL.
10. Scraped the surface with a sharp knife.
11. Could see plastic shavings under the scope.
12. Applied several drops of HCL and observed a strong reaction.
13. After several seconds, rinsed off HCL and dried.
14. Observed a clear plastic area. Conclusion, once the HCL found a path to the aluminum, it attached the foil between the layers.
15. Applied several drops of DCM on clear area and observed reaction of DCM on the clear area.

Smaller heat sealer temperature range reduces the cracking pressure variability.

Earlier tests resulted in highly variable cracking pressure. A quick test of the temperature controller showed a temperature range of 24°F. To tighten this temperature range, a second thermocouple was attached to the donut sealer. The thermocouple was connected to voltmeter which was read to 0.1 mv. By watching the voltage reading, we were able to reduce the temperature range to 6°F.

Colder ambient temperature increases cracking pressure.

Full size bags with cracking pressure greater than 6.5 psi can be filled within 5 seconds.

Bags that have been "on the shelf" for 3 months can be opened in shallow and in deep water.

On 31 January 1991, ten bags that were manufactured late September 1990 were pumped in WHOI pressure tank at 9000 psi. In December 1990, these bags had been subjected to a high pressure leakage test. The worst bag leaked 0.15 g of water during the high pressure leakage test. During the high pressure pumping test, all 10 of these bags opened, but two didn't completely fill.

Table 17: Room Temperature Cracking Tests

Heat Sealer setting used: Temperature: 225° F nominally Dwell Time: 3.5 seconds Pressure: 26 psi		
Results: Coupons Tested	10	44
Cracking Pressure (psi) Minimum Maximum Mean	 4.98 10.68 8.28	 6.34 8.41 7.64
Standard Deviation	2.14	0.46

Table 18: Cold Cracking Tests

Heat sealer settings used Temperature: 225° $\pm$ 3 ° F Dwell time: 3.5 seconds Pressure: 26 psi Cold water samples equilibriated in the coald water for a minimum of 35 minutes		
Results: Water temperature Number of Coupons tested	 15° C 44	 < 3° C 20
Cracking Pressure Minimum Maximum Mean Standard Deviation	 6.34 8.41 7.64 0.46	 7.29 8.95 8.07 0.46

Table 19: Tests on thirteen full size bags

Time Filling Time (psi)	Cracking Pressure	Cracking Time	Filling Time
Set of 5			
Minimum	6.62	0.36	2.65
Maximum	7.83	0.78	2.81
Mean	7.21	0.54	2.74
Standard Deviation	0.53	0.08	0.08
Set of 9			
Minimum	7.94	0.42	2.17
Maximum	9.76	1.06	3.12
Mean	8.56	0.61	2.60
Standard Deviation	0.55	0.22	0.29
* Have incomplete data on a tenth one with 8.56 psi cracking pressure and 2.24 s cracking time			

On 28 December 1990, fifteen bags that were manufactured late September 1990 were pumped in the dynamic cracking pressure setup. Fourteen out of 15 of the bags opened and filled with cracking pressure ranging from 8.52 psi to 11.29 psi. For the failed bag, the pressure peaked at 11.66 psi.

As can be seen in the previous data, the nominal donut heat sealer settings are temperature = 225 °F, dwell time = 3.5 s, and pressure = 26 psi.

New Sample Confirmation Concept (Differential Pressure)

For sample confirmation, a paddlewheel flowmeter was installed at the inlet of the pump to measure the volume of water pumped. During dockside testing and at-sea trials, the results of the flowmeter were inconclusive. At first, the problem was attributed to the software algorithm, and the need for more calibration tests. Based on hundreds of coupon/bag opening tests conducted in the laboratory while measuring both differential pressure and flow rate, it has been determined that the leakage rate around the drawer is too high to clearly differentiate between a bag that opens and fills to one that fails to open. An analysis of the differential pressure profile during more than 125 bag opening and filling tests indicates that differential pressure can be used for sample confirmation. Fig. 26 shows three differential pressure profiles. The primary profile which is marked with letters show a bag that successfully opened and filled. From point A to point B, the differential pressure in the drawer is increasing. At point B, the bag opens, causing a rapid decrease in differential pressure. From point B to point C, the bag is rapidly filling with little resistance from the expanding bag. At point C, the near-full bag becomes more resistant to expansion, thereby causing an increase in differential pressure. At point d, the bag stops filling and the resulting differential pressure is due to the resistance of the water entering the drawer around the lid. The other two differential pressure profiles show two failure modes.

The differential pressure sample confirmation concept provides sample confirmation, cracking pressure, time of opening, filling time, and indication of volume collected.

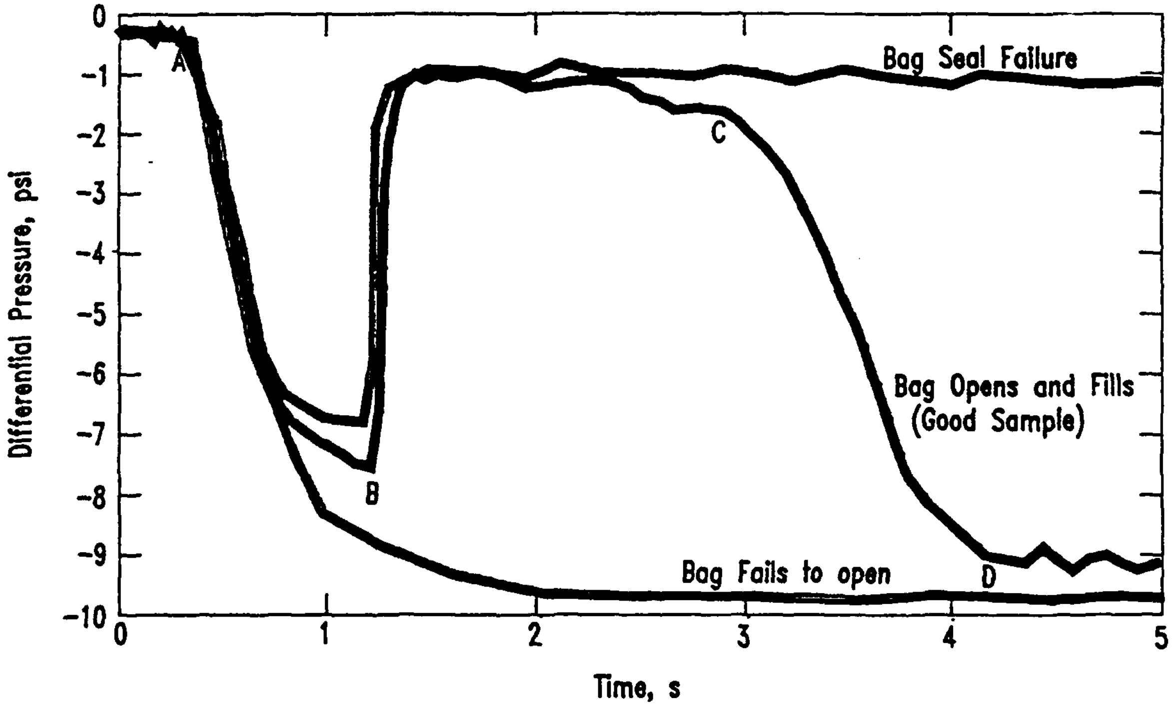


Figure 26: Sample Differential Profiles

CONCLUSIONS

In this section of the report, we summarize the achievements as well as the difficulties encountered during the water sampler prototype development program. Next, the advantages that an improved version, with the present shortcomings removed, would provide to a scientific community primarily interested in safely and routinely gathering large volumes of uncontaminated sea water are presented.

The authors believe that the technology for collecting sea water with the help of clean, flexible bags at any point within the water column offers a great research potential for the oceanographic community. Areas of R&D that should be pursued and possible applications for this technique conclude this section.

Achievements

The development of the Water Sampler Prototype took place in three distinct steps. 1) Preliminary, conceptual design of the entire, integrated system, 2) design, construction and evaluation at sea of the underwater and deck control units, and 3) sampling bag improvements.

Step 1: During the initial eight months (October 1, 1988 to May 31, 1989), the conceptual design of the four modules constituting the Integrated Water Sampler was pursued and completed. As previously described these modules were:

- The underwater unit, that is the cable lowered hydrodynamically profiled frame, containing the sea water acquisition subsystem and its controls, and the associated profiling instrumentation (CTD and altimeter).
- The deck control unit, which automates water sampling operations, and stores and displays oceanographic data acquired during the cast.
- The handling and stowage unit, which allows the semi-automatic deployment and recovery of the underwater unit and provides safe storage between casts.
- The water sample transfer equipment for the easy, free-of-contamination extraction of seawater samples from the underwater unit.

The principal achievement of this first step was a substantial technical report [6], written by engineers and scientists of WHOI and Battelle. This informative report describes in abundant details the innovative engineering concepts fundamental to the water sampler performance; in particular, the elegant filling method of flexible bags by pressure differential between ambient and bag compartment pressures, the ingenious magnetic bag closure, the unique sensor controlled, hydraulic handling and stowing deck gear, the quick electromechanical cable connect/disconnect termination, and the automated motion compensated profiling procedure.

Step 2: The initial step was followed by an intensive effort of design, construction, testing and evaluation at sea of an actual water sampler consisting of the underwater and the deck control units. Step 2 spanned from August 1, 1988 to June 1, 1990, with only six months of that time actually spent for the completion of the full size prototype and its controls. That this unique, complex system, which integrates so may new mechanical and electrical components could be built and deployed at sea by so few engineers, over such a short time, is indeed the major achievement of Step 2.

Withstanding the risk of repetition, it is fitting to mention the major components, or "pieces," which were designed, built or procured assembled and tested, and finally integrated in the water sampler prototype.

These components were:

The frame which houses 36 trays containing the seven liter plastic water sample bags, the rotary valve which selects the individual bag to be filled, the pump and its deep submergence electrical motor, the battery pack, and the exhaust valves. Also mounted in the frame were the altimeter, the Mark III Neil Brown Instrument Systems CTD instrument, and the telemetry and control electronics. At the shipboard end of the cable, a battery of computers were used to communicate with the lowered unit and to display and store the scientific and engineering data acquired.

The water sampler performance was first tested at sea in a short shake down cruise in March 1990. A deep sea cruise, from Woods Hole to Bermuda and return, followed in April 1990. During this evaluation cruise, twenty-one casts were made, including five to depths in excess of 4000 meters. Lowering speed ranged from 0.5 to 2.0 meters/second. Results from this cruise have been presented in detail. In summary, the positive points were as follows:

<u>Electronics:</u> All electronic components of the sampler functioned very well for such a complex and new system. The telemetry between the ship and the underwater unit was excellent, with little or no distortion of the CTD data stream introduced by superimposed sampler control commands. The power supply, controller, cabling, motor and pump assembly were operative at all times. The specially procured bottom-finding altimeter was able to detect and follow the bottom from an altitude of greater that 1,500 meters. Minor problems in the telemetry link and orientation sensors were discovered and a solution proposed which needs to be implemented.

<u>Mechanical:</u> A new, robust electromechanical termination, to attach and connect the one-ton sampler to the CTD cable proved to be practical and functional [5]. The rotary valve, its motor and controls used for the drawer selection, also worked well. The pump was repeatedly and successfully turned on and off over the entire temperature and pressure ranges of every cast. The temporary launching technique proved to be adequate for the safe deployment and recovery of the water sampler in moderately rough seas.

Two problems were identified that had a major impact on the data quality. Bags were found to develop air and water leaks in quantities sufficient to destroy or at least raise the question of sample integrity. In addition, records of tilt and spin indicated that the water sampler had poor flight characteristics, particularly when traveling downwards at high speed.

Following an assessment of the components that worked well and others needing reevaluation, a consensus was reached by the project principals and the NSF Program Manager that the basic sampler design remained viable and that work should be pursued, placing priority on first solving the bag issue.

<u>Step 3:</u> The final step, as far as R&D effort was concerned, was entirely devoted to the improvement of the water collecting plastic bags. This step lasted from October 1990 to April 1991. By then the problem of water leakage prior to collection of samples had been solved, at least on small, pilot runs of well controlled bags.

To solve the bag leakage problem, a new approach was pursued and demonstrated to be valid. In this approach, the two plausible causes of bag leakage, namely through the seals or through the valve would be first produced. The bags would remain closed until sampling was required. The pressure differential created by the pump would be used to rupture a

preweakened bag area or seal. After filling, the bag would remain hermetically closed with a tight, secure closure mechanism.

This approach had several advantages: it eliminated air leakage and contamination on deck prior to deployment; it reduced at-sea storage requirements; and it kept most of the existing water sampler design features intact.

The criteria for success were to fabricate seven liter bags which 1) when kept sealed would absorb less than one cc of water while being subjected to two hour cycles of hydrostatic pressure simulating a round trip from the surface down to 6000 meters, and 2) would completely and reliably fill, on command, at any pressure over this depth range.

To implement this program, an elegant bag rupture mechanism was engineered by of Battelle Memorial Institute. A 5 cm circular opening was cut in one sheet of the bag. This opening was then sealed to the other sheet with the use of a donut-shaped heat sealer. The pressure differential, when applied by the pump, would force the two sheets apart, peel off the circular seal and enable water to enter and fill the bag. To prove the validity of this novel design, more than 600 tests were performed in the fall and winter of 1990 on bags equipped with the donut seal. These tests positively confirmed that 2) bags could be fabricated which leak less that one cc of water when subjected to a full 6000 meters immersion cycle, 2) these bags could be repeatedly ruptured open and filled at all depths between the surface and 6000 meters, and 3) positive sample confirmation could be obtained by monitoring the differential pressure across the pump.

In summary, at the end of the Water Sampler Prototype development effort, the following had been accomplished.

- The prototype of a water sampler underwater unit, with controls, had been built and tested at sea.

- The electronic subsystem for activating and controlling water sampling and for telemetering standard CTD data had been built and proven to be satisfactory.

- Remotely controlled pumping and filling of seven-liter bags had been achieved with reasonable success at all specified depths, both in pressure tanks and at sea.

- The problem of water leakage prior to collection of samples had been resolved.

Critical engineering and scientific issues remaining to be investigated and resolved included:

- Sample bag closure
- Flight stability of the water sampler
- Automated profiling procedure and equipment, including motion compensation and automation of payout winch.
- Design and fabrication of overboard handling and inboard stowage subsystems
- Water withdrawing and transfer to the lab subsystems
- Electronic and mechanical system integration
- Demonstration of water sampler scientific performance, both in improved quality of data and superior efficiency, when compared to existing water sampling and profiling instrumentation

System Advantages

Assuming: 1) the issue of bag and closure leak tightness is resolved, 2) the water sampler is capable of profiling the water column in a fast, smooth, automated, wave decoupled manner, and 3) its handling overboard in rough weather is made safe and practical by its hydraulic launch and recovery equipment, (Note: all assumptions are realistic) then this operational water sampler and data acquisition system would offer the following advantages:

- The size and compact arrangement of its water collecting bags would permit the acquisition of large volumes of sea water.
- Its reduced cross section and hydrodynamic shape, would enable profiles to be made at much higher speeds. This translates to a substantial time savings, thus increasing the efficiency of a particular cruise, or reducing the length of time spent at sea for a particular survey.
- Samples could be drawn without stopping, on the way up or down, thus averaging water properties over a known stratum, and also reducing cast time. Furthermore differential pressure measurement can positively confirm sample acquisition from any particular tray selected.
- The inside of the sampling container (the plastic bag) is never exposed to the ship's atmosphere, or the surface water, thus reducing considerably the chances of contamination and eliminating the need for flushing.
- Since flushing is not required, samples can be taken at or near the surface on the way down.
- The use of flexible bags would completely eliminate air contamination whenever withdrawing water from the bag.
- The side mounting of the CTD sensors would permit acquisition of CTD profiles of equal quality on the up and down casts.
- The loss of CTD data, particularly from the oxygen sensor, when activating and performing water sampling would be eliminated.
- Finally, the adjunction of a motion compensator and of an hydraulic launching and recovery system would permit casts to be done smoothly, in rougher seas, and with less risk and greater ease.

The advantages would constitute a great improvement in the state of the art for routinely gathering large quantities of uncontaminated sea water and high quality hydrological data. Such a system would also substantially reduce the cost of these operations.

Further R&D Applications

Among the many R&D projects required for the completion of an operational water sampler, with the capabilities mentioned above, none is more critical nor has more potential than the development of a fully reliable plastic sample container and its closure for the acquisition and the preservation of a clean water sampler.

These containers, or bags, together with their closing mechanism must eventually be mass produced and be of modest cost. They must be free of

contamination during their fabrication as well as during their shelf life. The walls, the seams, and the closures must be absolutely impermeable and leak tight, preventing the incursion of air and/or water, at atmospheric pressure as well as at 6000 meter of immersion. Furthermore their leaktightness and chemical cleanness must be preserved before as well as after bag filling. Setting the specifications for the expected performance of such bags, and pursing a focused, limited R&D program to enable their industrial production would be arduous but rewarding indeed.

In addition to traditional water sampling conducted from ships lowering or towing water samplers, moored and free drifting applications of great interest can be envisioned.

- Long Term Sampling of the Water Column. A mooring set in the deep sea could support a number of "compact" water samplers, distributed at "strategic" locations between the surface and the bottom. At programmed time intervals, each water sampler would fill a bag full with ambient water. At the end of its scheduled deployment, the mooring would have gathered a collection of water samples which, when analyzed, could help describe the evolution of the water chemical properties, both as a function of time and depth. For example one could envision a mooring with five water samplers, each containing 24 bags. At the end of one year, assuming a sampling rate of two samples per month, the mooring would have collected 120 samples. Each water sampler could thus provide a one-year time series, with a biweekly time interval, of water properties at the sampler depth.

- Long Term Monitoring of Specific Sites. Sites of great scientific and ecological relevancy to modern society abound in the shallow and deep waters of the world. Deep sea volcanic activities, areas of plankton bloom, offshore discharge of effluents, active or contemplated dumping sites, major accidental pollution areas (ship wrecks), etc., are examples of these specific sites. The deployment and the recovery of automated water samplers at these sites could greatly enhance the quantity and the quality of observations obtained by other means. It could provide "ground truth" to update and post calibrate water monitoring sensors mounted on surface or subsurface buoys. It could replace these buoys in areas where real time information is not essential. The distribution of samplers around pollution source, such as a lost submarine or a contaminated material dump site, could be of tremendous help in ascertaining the transport and the diffusion of the pollutants as a function of time and space. Conditional sampling algorithms in on-board microprocessors could control the times of sample acquisition to coincide with highly energetic or unusual events.

- Drifters. The acquisition of uncontaminated water samples, obtained with automated water samplers mounted on free drifting platforms, should be of interest to a wide spectrum of oceanographic disciplines. Surface drifters equipped with a submerged trailing cable, could support a number of samplers distributed from the surface down to say 1000 meters. A knowledge of the time and position of sampling would be derived from the on-board clock and satellite location (Argos or GPS). Subsurface drifters, operating in the SOFAR or RAFOS mode, could also provide "Lagrangian" sampling at predetermined depths.

- Underwater Vehicles. The acquisition of seawater samples at precise locations could be made from manned submersibles, tethered remote vehicles or autonomous underwater vehicles. ALVIN could

control the precise location for the collection of uncontaminated samples around hydrothermal vents. An ROV, under control from a surface ship, could take samples at wreck or dump sites to explore for potential leakage of contaminates. Finally, and AUV could do remote collection of samples in high risk areas, during routine survey operations, and in a conditional sampling exploratory mode.

All of these techniques require the recovery of the platforms at the end of their sampling deployment for laboratory analysis of the water samples obtained. The sampler technique would allow the retrieval of large volumes of uncontaminated water samples in a manner now not possible.

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APPENDICES

A: Project Chronology

In response to RFP Number OCE 87-112, the Woods Hole Oceanographic Institution (WHOI) of Woods Hole, Massachusetts, with Battelle Memorial Institute as a subcontractor to WHOI, submitted on August 5, 1988, WHOI Proposal No. 5423.1 to the National Science Foundation (NSF) for the design, fabrication and testing of an Integrated Seawater Sampler and Data Acquisition System for the Ocean Sciences. The WHOI/Battelle proposal was reviewed and approved, and Contract Number OCE 8821977 was issued to WHOI by NSF on September 30, 1988. Work on the water sampler started immediately under the leadership of Messrs. L. Clark, Program Manager at NSF, H. Berteaux, Principal Investigator at WHOI, S. McDowell, Physical Oceanographer, and C. Albro, Project Engineer, both of Battelle Memorial Institute.

Phase I (October 1, 1988 - May 31, 1989)

The development of the water sampler was pursued in two distinct phases. The initial eight months, Phase I, were devoted to the conceptual design of the four modules, constituting the Integrated Water Sampler System, namely:

1. The underwater unit, that is the cable-lowered water sampler with the seawater acquisition subsystem and its controls, and the associated profiling instrumentation (CTD, oxygen, and altimeter).

The initial operational requirements for the underwater unit were:

- Profiling speeds (descent and ascent) of up to two m/sec.
- The water sampler should be capable of collecting 36 ten liter samples of uncontaminated sea water during descent and/or ascent.
- The underwater unit should accommodate CTD instruments from leading manufacturers.
- The underwater unit should be equipped with a bottom finding altimeter that can be electronically interfaced with the deck control unit.

2. The deck control unit, which automates water sampling operations and stores/displays oceanographic data acquired during the cast.

3. The handling and deck stowage unit, which allows the deployment and recovery of the underwater unit with a minimum of risk to personnel and equipment and provides secure storage while underway.

4. The water sample transfer unit to enable users to routinely extract samples from the underwater unit, while maintaining strict sample integrity.

The project activities which were conducted during Phase I included:

- A Scientific Specifications Meeting was held at WHOI on October 19, 1988. The purpose of the meeting was to (1) assemble the team of project engineers and oceanographers and review the design concepts that were in the initial proposal to NSF, and (2) discuss the sampling requirements of the WOCE Hydrographic Program which would ultimately govern the specifications for the new water sampling system. The meeting was attended by 22 scientists and engineers -

eleven from WHOI, seven from Battelle, one from Scripps Institution of Oceanography, one NSF representative, and two consultants.

- Next the design team formulated preliminary design concepts for all major components of the system.

- A Preliminary Design Review Meeting was held at WHOI on December 14, 1988. The purpose of the meeting was to review the preliminary design of the individual system components and discuss integration of the entire system. Fifteen scientists/ engineers of the WHOI/Battelle team attended the meeting.

- During the period from December 1988 through March 1989,the design team finalized the conceptual design of the water sampler and prepared drafts of the Conceptual Design Report. The evaluation of trilaminate material candidates to fabricate the flexible water containers (bags) was also systematically pursued by scientists of the WHOI Chemical Oceanography Department.

- On March 30, 1989, four members of the water sampler design team (Berteaux, Bullister, Albro, and McDowell) met with the WOCE Hydrographic Program Implementation Panel in Dallas, Texas. At this meeting, the design team gave an oral presentation of the conceptual design of the water sampler, accompanied by scale models of components and a video tape of an engineering bag test. The presentation was followed by an open discussion between the design team and the WOCE panel members.

- On May 5, 1989, the WHOI/Battelle team submitted a revised proposal for Phase II, Prototype Construction, Testing, Evaluation, and Documentation, of the integrated seawater sampling system.

- At the completion of Phase I, a substantial technical report was written by engineers and scientists of WHOI and Battelle, which described the working principles, the main components and the cost estimates of the four modules. The conceptual design report was submitted to NSF on May 31, 1989.

The conceptual underwater unit (Fig. A-1) consisted of the following major components:

- The water sampler which is the water collection system within the underwater unit. The water sampler includes the frame and drawers, the pump and associated flow control and the flexible water sample containers. Within the water sampler unit are 36 drawers each holding a 10-liter sample container.

- The CTD system includes the pressure case and sensor package. This high-resolution profiling system may be configured with additional sensors, such as for measurement of dissolved oxygen, pH, turbidity, and other chemical parameters.

- The water sampler control package receives sampling information from the surface and actuates sampling through the sampler control module. The electronic control package also interfaces to the CTD and altimeter, and transmits all data to the surface.

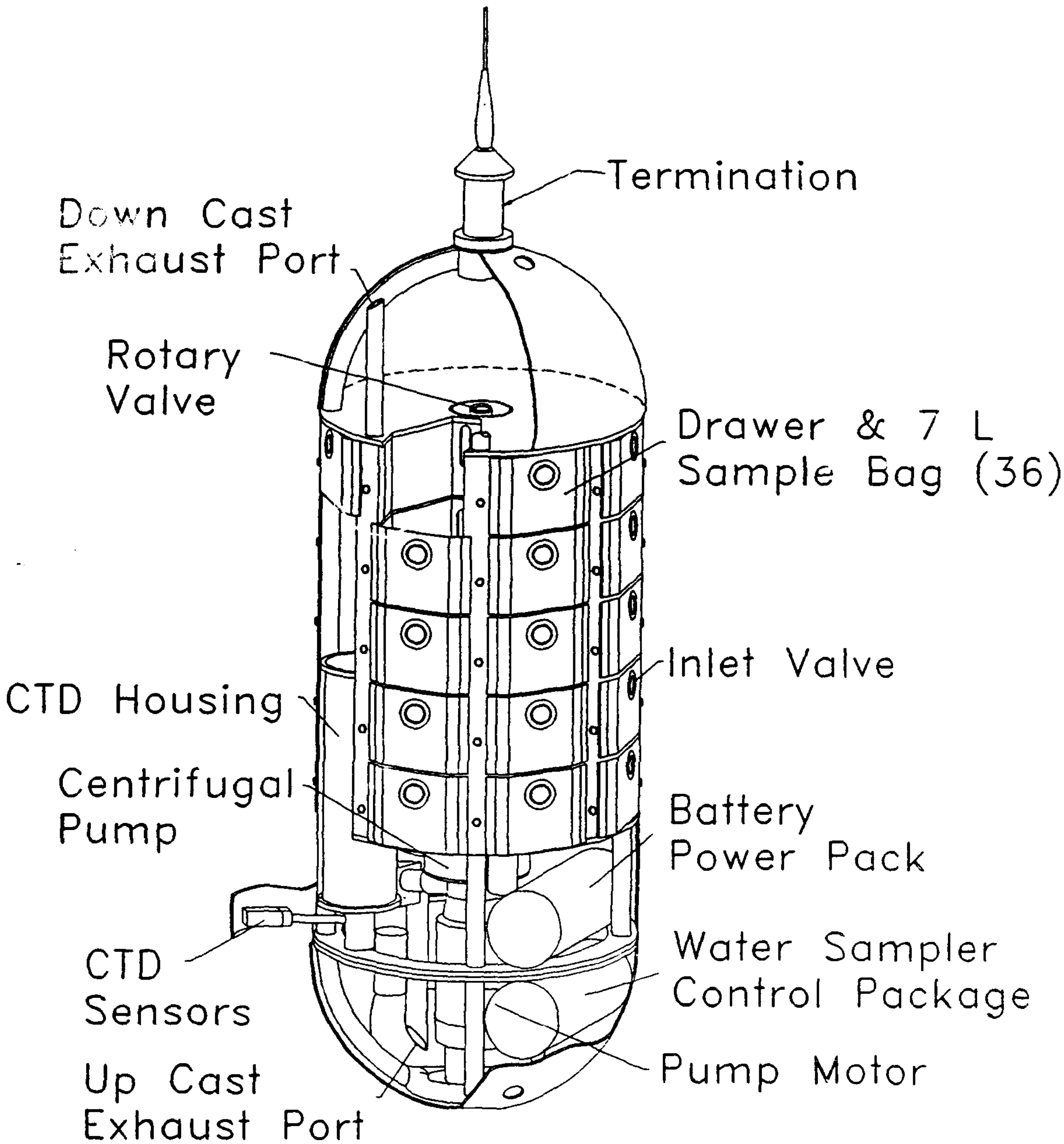


Figure A-1: Underwater Unit Conceptual Design

- The bottom-finding altimeter is an acoustic pinger interfaced to the water sample control package to inform laboratory personnel and the winch operator of underwater unit's distance off the bottom.
- The structure and termination of the underwater unit consists of the internal frame supporting the payload (i.e., water sampler unit and other components), the outer fairing for reducing drag during profiling, syntactic foam for flight stability, and the electromechanical termination for attaching the underwater unit to the lowering cable.
- The rechargeable battery power pack provides power to the water sampler so that the lowering cable provides only CTD data transmission and water sampler communication channels.

The innovative, conceptual handling and stowage unit, which was never built, is presented in Appendix D of this report. Details of conceptual design for the four major components of the integrated system can be found in the Phase I final report.

Phase II (August 1, 1989 - December 31, 1992)

On June 27, 1989, members of the water sampler design team, the NSF Program Manager and members of the WOCE Scientific Steering Committee met in San Francisco for a project review meeting. Comments received from proposal reviewers and potential users resulted in a reduction of the water sample volume from the originally specified ten liters to seven liters. No other changes were made in the original requirements.

On August 1, 1989, the initial contract was extended, and progressive incremental funding was provided at the completion of critical steps as the project progressed. Because of unforeseeable development difficulties, the initial objectives of the Phase II proposal could not be achieved within the time and money constraints. Instead, emphasis was placed on the fabrication and testing of the underwater unit and its controls. The water transfer system was not optimized. The handling and stowage system designed in Phase I, which included a recovery and launching hydraulic unit and a motion compensator (Appendix D), were not addressed. The salient points and results of Phase II are hereafter summarized. The underwater unit prototype was designed and built during the first six months of Phase II. As shown in Fig. A-1, its main components included: the frame, which houses 36 trays containing the trilaminated, plastic water sampling bags, the rotary valve, which selects individually the bag to be filled, the exhaust valves, the pump and its motor, the battery pack, the Mark III NBS/CTD, the altimeter, and the telemetry and control electronics. The water sampler dimensions, shape, weight and the location of its components are shown in Fig. A-1.

After an intensive series of component and subsystem tests, including a short shakedown cruise (March 15-16, 1990), the water sampler was taken to sea for a comprehensive series of engineering and scientific evaluation tests (R/V OCEANUS, Voyage #219, Woods Hole to Bermuda and return to Woods Hole, April 16-May 3, 1990). During this evaluation cruise, a total of 21 casts were made, including five to a depth in excess of 4000 m. Lowering speed spanned from 0.5 to 2.0 m/sec.

The results of the sea trials showed that the prototype performed well in some areas but sample bag leakage and flight stability were two major problems. The positive features demonstrated on this cruise included:

ELECTRONICS: All electronic components of the sampler functioned very well for such a complex and new system. The telemetry between the ship and

the underwater unit was excellent, with little or no distortion of the CTD data stream introduced by superimposed sampler control commands. The power supply, controller, cabling, motor and pump assembly were operative at all times. The specially procured bottom-finding altimeter was able to detect and follow the bottom from an altitude of greater than 1,500 m. Minor problems in the telemetry link and orientation sensors were discovered and a solution proposed which needs to be implemented.

MECHANICAL: A new, robust electromechanical termination to attach and connect the one-ton sampler to the CTD cable proved to be practical and functional. The rotary valve, its motor and controls used for the drawer selection, also worked well. The pump was repeatedly and successfully turned on and off over the entire temperature and pressure ranges of every cast. The temporary launching technique proved to be adequate for the safe deployment and recovery of the water sampler in moderately rough seas.

Two problems were identified that had a major impact on the data quality. Bags were found to develop air and water leaks in quantities sufficient to destroy or at least raise the question of sample integrity. In addition, records of tilt and spin indicated that the water sampler had poor flight characteristics, particularly when traveling downward at high speed.

Following an assessment of the components that worked well and others needing reevaluation, a consensus was reached by the project principals and the NSF Program Manager that the basic sampler design remained viable and that work should be pursued, placing priority on first solving the bag issue.

To solve the bag leakage problem, a new approach was pursued and demonstrated to be valid. In this approach, the two plausible causes of bag leakage, namely through the seals or through the valve, were to be treated separately. An hermetically heat sealed, clean bag would be first produced. The bags would remain closed until sampling was required. The pressure differential created by the pump would be used to rupture a preweakened bag area or seal. After filling, the bag would remain hermetically closed by way of a tight, secure closure mechanism.

This approach had several advantages: it eliminated air leakage and contamination on deck prior to deployment; it reduced at-sea storage requirements; and it kept most of the existing water sampler design features intact.

In September 1990, an independent engineering review panel of outside professionals, under the chairmanship of David V. Burke, Jr., Vice President of Engineering, Charles Stark Draper Laboratory, was convened to critically review the entire water sampler concept and its present design and to make specific recommendations for improvement as deemed necessary. The panel reported that, "no performance requirements seem to be unrealistic or not achievable, although several system improvements are required before success is achieved. The priority of problem resolution identified by the WHOI and Battelle teams is the right one; in particular, the subsystem for obtaining and sealing the water samples must be altered and then demonstrated as meeting its specifications, including reliability."

Following the review, an accelerated program for developing and testing improved water sample containers (bags) was initiated and diligently pursued. The criteria for success were to fabricate seven liter bags which 1) when kept sealed would absorb less than 1 cc of water while being subjected to two hour cycles of hydrostatic pressure simulating a round trip from the surface down to 6000 m, and 2) would completely and reliably fill, on command, at any pressure over this depth range.

To implement this program, an elegant bag rupture mechanism was engineered by C. Albro of Battelle. A 5 cm circular opening was cut in one sheet of the bag. This opening was then sealed to the other sheet with the use of a donut-shaped heat sealer. The pressure differential, when applied by the pump, would force the two sheets apart, peel off the circular sea and enable water to enter and fill the bag. To prove the validity of this novel design, more than 600 tests were performed in the fall and winter of 1990 on bags equipped with the donut seal. These tests positively confirmed that 1) bags could be fabricated which leak less than 1 cc of water when subjected to a full 6000 m immersion cycle, and 2) these bags could be repeatedly ruptured open and filled at all depths between the surface and 6000 m. At the conclusion of the bag testing program in the spring of 1991, the following had been accomplished.

- The prototype of a water sampler underwater unit, with controls, had been built and tested at sea.
- The electronic subsystem for activating and controlling water sampling and for telemetering standard CTD data had been built and proven to be satisfactory.
- Remotely controlled pumping and filling of seven-liter bags had been achieved with reasonable success at all specified depths, both in pressure tanks and at sea.
- The problem of water leakage prior to collection of samples had been resolved.

Furthermore, throughout Phase II, communications and dissemination of information with project team members, NSF sponsorship, and the scientific community was diligently pursued. This activity included working meetings with WHOI and Battelle scientists and engineers scheduled every two weeks, monthly internal progress reports sent to NSF, summary of important development steps and status reports sent to the WOCE community (telemail), a widely attended "Water Sampler," a three-hour long seminar given at WHOI on November 24, 1989, and presentation of formal papers and poster sessions at various scientific meetings (See References).

By then, critical engineering and scientific issues which remained to be investigated and resolved to complete the integrated water sampler and achieve the original objectives included:

- Bag closure after filling of water sample container
- Flight stability of water sampler at high lowering speeds
- Design and fabrication of the handling and stowage, and, of the water transfer subsystems.
- Electronic and mechanical system integration
- Demonstration of water sampler scientific performance, both in improved quality of data and superior efficiency, when compared to existing water sampling and profiling instrumentation.

At NSF request, a proposal was written to address these issues, with Drs. J. D. Irish and W. J. Jenkins of WHOI as Co-Principal Investigators, Messrs. H. O. Berteaux and C. Albro being Associate Investigators. The goals of the proposal, as summarized in the Technical Abstract read as follows:

"This proposal addresses the engineering modifications necessary to complete and test the prototype Integrated Water

Sampler, and carry out an extensive evaluation cruise. Improved clean, sealed water sample bags and their closures need to be produced at a reasonable cost. Flight stability of the water sampler needs to be improved to reduce tension loading on the cable and to avoid contaminating the CTD data or water samples by turbulent or stagnant flow. Deck handling and motion compensation equipment are needed for quicker and safer handling of the water sampler at sea. When these modifications are completed and demonstrated in the laboratory, at dockside and in sea tests in the Atlantic, a tests hydrographic cruise will be undertaken with scientists from the Scripps Institution of Oceanography at a Pacific GEOSECS station to fully evaluate the actual performance of the integrated water sampler. This will demonstrate the speed at which samples can be taken, the quality of the continuous profiles, and the precision of water analysis possible with the gathered water samples."

This substantial document, requesting $2,724,927 over eighteen months, was submitted to NSF on June 20, 1991. After careful review and the convening of a special focus panel with expertise and experience in the scientific, engineering, and managerial aspects of this complex project, the decision was made by NSF not to pursue the development and the completion of the Integrated Water Sampler System as proposed. Reasons given for this negative decision included;

- Bag sealing and opening test results were not found convincing enough to warrant a major continuation of the project.
- Procedures for reliable production and criteria for quality control of industrial bags were not clearly identified.
- Program milestones and measures for success or failure of progressive steps were not strongly apparent.
- Not enough qualified experts to address specific problems identified in the proposal.
- Schedule too ambitious.

In short, the proposal and the presentation made to the panel on August 8, 1991 failed to build confidence that the project could and would be done within reasonable time and financial limits.

The proposal review also indicated that water sampling capabilities of the mid 1980's have been improved by recent advances made in the technology, another influential decision factor. The review mentioned, however, that the concept of water sampling by filling evacuated, clean bags has merit and is worth pursuing. Applications could be envisioned for profilers, moorings, submersibles, and bottom stations.

As part of the review, WHOI was invited to submit a close up proposal to consolidate and document the development efforts performed to date. This proposal, submitted to NSF January 14, 1992, was funded April 3, 1992. This report constitutes the bulk of the work covered in this final proposal.

B: SeaScan Altimeter

SAIL control specification

The hardware interface is the open collector variation of the SAIL interface. The pullup resistor value is determined by the cable length you need to use and must be included in the controller.

The software protocol conforms fully to the SAIL standard, IEEE 997-1985. It initializes at 9600 baud, 8 data bits and ignores the 8th (parity) bit. It can therefore be used with the other SAIL components that employ parity. When sending, it always sends bit 8 as a zero.

The WHOI software version 1.3 altimeter eliminates the SAIL baud switch command which was used in earlier versions. It also replies in hexadecimal format for the depth command instead of decimal as in the original version. This frees sufficient program space to suport holding of configuration parameters in EEPROM. See the C and M commands below.

The SAIL address is #MA and is followed immediately by a control or data command. The sequesnce #MAH will elicit the e\ghelp file for example. All commands may be entered after the prompt without including the #MA each time. Any invalid command will unaddress the altimeter.

All commands to the altimeter will return the prompt sequence, [cr][lf] : [etx]. This insures that the command has been received.

All control commands have numeric arguments. These are input as decimal values and leading zeros may be omitted. The entry must be terminated with either a [cr] or a space. Excess leading characters are also ignored. Thus the Pdd[cr] command which sets the output power to dd% of full power expects to use only the last two digits, and would interpret the input P123455[cr] as 56%.

Data Command

#MAD (reply "hhhh[cr][lf][etx]") The value, hhhh (four hex digits) is the distance to the nearest target in decimeters. It is calculated with an assumed speed of sound of 1500 m/sec. The time delay is measured from the start of the ping gate pulse to the first edge of echo detector reply. The maximum accepted delay is 7.99 seconds. Note the maximum value is 65535 decimeters or 6553.5 meters.

Control Commands

<u>#MABnnnn[cr] (reply "[cr][lf][etx]":</u> This command will set a blanking interval of nnnn milliseconds after the end of the transmitted pulse. This is necessary to allow the transducer to stop ringing after sending out a high power ping. This ringing looks to the receiver like an echo and is indistinguishable from nearby volume reverberation or echos. The receiver must be kept "numb" for this period. Since the exact ringing time is impossible to predict without taking into account the entire acoustic environment, we feel some control is required. Leading zeros are assumed, hence B99[cr] will set the interval to 99 ms. This value is saved in EEPROM by the M command.

<u>#MAWnn[cr] (reply "[cr][lf][etx]"):</u> This command will set the transmitted pulse width to nn milliseconds. The value of nn is 1 to 20. The power on default is 10 ms; the altimeter will not accept a value great than 20 ms. This value is saved in EEPROM by the M command.

#MAPnn (reply "[cr][lf][etx]"): This comand will set the acoustic power level of the transmitter to nn% of max power. The altimeter will accept inputs in the range of 0-99. (It will interpret P100 as 0% since it uses only the last two digits.) This value is saved in EEPROM by the M command.

#MARnn (reploy "[cr][lf][etx]"): Command to set the ping rep rate to nn seconds. This value is saved in EEPROM by the M command.

#MAM "Memorize": This command is used to "Memorize" the setup parameters in EEPROM. The altimeter will use these values next time it is powered up. The parameters are pulse rep rate, pulse width, power level and blanking interval. They may be changed at any time using the commands above (R, W, P, B) but these values will not be copies to EEPROM until the M command is issued.

#MAC View Current Configuration parameters: The C command will list the current configuration values. Unfortunately, there is not enough ROM space to convert the reply to engineering units; therefore, the raw hexidecimal values in the registers are output. The output format will be:

#MAC[cr][lf]0050 44pp bbbb bbbb wwww[cr][lf]:[etx]

where

0050 = RAM address where these are stored
rr = ping period in hex seconds (01-08 typically)
pp = power level, $00-$FD
bbbb bbbb =blanking interval, made of the sum of ...
byte 1 integer seconds (00-07)
byte 2 hundreddths of a second (hex) $00-$63
byte 3,4 clock tics at 1.2288 MHz ($0000-$2FFF)
wwww = pulse width, tics of 1.2288MHz, ($04D0-$6040)

(This command uses the data dump routines of the ?M command below to do its work, hence the leading 0050 which is the address of the first of these eight bytes.)

#MAH: This command elicits the brief Help file which is a short list of these commands and the date of the last program modification.

#MA[space]: The [space] character is a valid command which does nothing except return the prompt. It is often used to hold off the timeout when testing on the bench (if the timeout is included) or to see if the unit is still there when the operator is working through a long communication chain of modems.

?Maaaa dddd[cf]: This command will dump dddd bytes of memory starting at address aaaa. It is used in testing and not normally useful in an operational mode. Leading zeros are assumed and need not be entered. The aaaa field is terminated by a space and the dddd field by a [cr]. The command ?MF800 8[cr] will show the EEPROM values of the configuration parameters which are used on power up.

!Maaaa dd dd dd...[cr]: This command will write into RAM. It puts data dd etc in RAM starting at address aaaa. It should be used only by an experienced operator who understands the memory locations and their contents. This command cannot write into EEPROM.

C: Cruise Summary Logs

The following tables contain information on the performance of the water sampler and altimeter during the March 1990 test cruises aboard the R/V Oceanus.

Detailed discussion of these tables and the general summary of the cruises is given in the "Testing and Evaluation" and "Testing and Evaluations Results" discussions above.

The altimeter summary tables list the altimeter height measured by acoustic techniques, the depth (in dbars) from the CTD pressure sensor, the acceleration of gravity, CTD specific volume anomaly, calculated meters depth, and estimated bottom depth. The Altimeter Delta column lists the difference in individual reading from the averaged calculated water depth, which is often significantly different than the tabulated depth from the ship's fathometer.

DATA FROM CAST 1 ON 16 MARCH 1990									
Drawer	Pumping Time (s)	Cumulative Time (s)	Time to Position Rotary Valve (s)	Depth db	Temp °C	Battery Voltage (vdc)	Flow Reading	Volume (L)	Bag Condition
0	30	30		15	9.7	48.27		0	
1	20	50	37	15	9.7	48.27		6.8	
2	10	60	17	15	9.7	48.06		8	
3	5	65	26	15	9.7	48.09		5.5	
4	0	65	27	15	9.7	48.09		0	
5	30	95	59	450	7.2	48.17		7.5	
6	20	115	29	500	6.6	48.21		6.4	
7	10	125	54	550	6.1	47.89		6.8	
8	0	125	27			47.89		0	
9	30	155	48	900	4.6	47.74		0	
10	20	175	26	968	4.5	47.87		7	1 hole
11	10	185	38	1024	4.4	47.69		7.1	
12	0	185	27			47.69		0	
13	30	215	27	1391	4.1	47.68		2	1 hole
14	20	235	25	1472	4.1	47.61		7.3	
15	10	245	27	1539	4.1	47.58		0	
16	0	245	52		4.1	47.58		0	
17	30	275	27	1850	4.1	47.9		0	
18	20	295	25	1850	4.1	47.18		7.5	
19	10	305	50	1850	4.1	47.09		7.6	
20	0	305	18			47.09		0	
21	30	335	26	1342	4.1	46.9	101	3.5	
22	20	355	30	1342	4.1	46.8	97	0	
23	10	365	52	1342	4.1	46.78	31	0	
24	0	365	35	1342	4.1	46.61	0	0	
25	30	395	27	897	4.7	46.61	105	7.9	
26	20	415	41	899	4.7	46.56	96	4.8	1 hole
27	10	425	44	899	4.7	46.55	170	0	broken lid
28	0	425	25	899	4.7	46.55	0	0.02	
29	30	455	23	451	7.2	46.24	105	6.1	
30	20	475	76	453	7.2	46.05	140	7.3	
31	10	485	28	453	7.2	45.73	93	8	
32	0	485	25	453	7.2	45.73	0	0.2	
33	30	515	27	16	9.7	45.33	254	2.6	1 hole
34	30	545	27	16	9.7	44.36	115	7.9	
35	30	575	26	14	9.7	43.85	91	7.5	
36	0	575	45	14	9.7		0	0	
PC = partial peeling of seam in corner of bag									

DATA FROM CAST 2 ON 16 MARCH 1990									
Drawer	Pumping Time (s)	Cumulative Time (s)	Time to Position Rotary Valve (s)	Depth db	Temp °C	Battery Voltage (vdc)	Flow Reading	Volume (L)	Bag Condition
0	30	30		23	9.7	49.31	169	0	
1	20	50	37	22	9.7	49.21	3	0	ok
2	10	60	17	22	9.7	49.28	7	0	1 PC
3	5	65	26	22	9.7	49.39	12657	0	ok
4	0	65	27	22	9.7	49.83	0	0	ok
5	30	95	59	484	5.8	49.13	4	0	ok
6	20	115	29	534	5.4	49.43	2	0.3	1 hole/bottom,1 PC
7	10	125	54	565	5.3	49.13	7	3.5	1 hole/bottom
8	0	125	27	640	5.1	49.75	0	0	ok
9	30	155	48	959	4.4	49.47	53	0	ok
10	20	175	26	1026	4.2	48.89	12	0	2 PC
11	10	185	38	1093	4.1	49.12	64	0	ok
12	0	185	27	1265	4.1	49.64	0	0	ok
13	30	215	27	1430	4.1	48.88	27	6.3	1 PC
14	20	235	25	1660	4.1	48.78	28	5.4	1 hole/top, 3 PC
15	10	245	27	1697	4.1	48.81	15	0	ok
16	0	245	52	1801	4.1	49.53	0	0	ok
17	30	275	27	1805	4.1	48.8	110	5.3	ok
18	20	295	25	1804	4.1	48.72	70	7.4	3 PC
19	10	305	50	1803	4.1	48.73	35	4.3	1 hole/top, 2 PC
20	0	305	18	1803	4.1	49.23	0	0	ok
21	30	335	26	1371	4.1	48.51	28	5.8	1 PC
22	20	355	30	1373	4.1	48.51	32	0	ok
23	10	365	52	1375	4.1	48.64	8	0	ok
24	0	365	35	1375	4.1	49.05	0	0	ok
25	30	395	27	895	4.5	48.4	29	5.2	1 hole/top, 1 PC, loose gasket
26	20	415	41	896	4.5	48.38	43	3.4	1 PC
27	10	425	44	897	4.5	48.24	53	7.2	gasket little loose
28	0	425	25	897	4.5	48.91	0	0.7	ok
29	30	455	23	324	8.9	48.22	33	2.5	1 hole/top
30	20	475	76	327	8.9	48.16	85	3.1	1 PC
31	10	485	28	329	8.9	48.24	81	7	1 PC
32	0	485	25	332	8.9	48.68	0	0.4	1 PC
33	30	515	27	34	9.8	48.08	107	7.1	1 PC
34	30	545	27	23	9.8	47.89	97	7.2	4 PC
35	30	575	26	22	9.8	47.93	218	5.5	1 hole/top, 2 PC
36	0	575	45	22	9.8		0	0	ok
	PC = partial peeling of seam in corner of bag								

Cruise 219 NSF Water Sampler Cast Log													
Cast:	A				Date:	16-Apr-90				Time in:	13:35		
Battery Set Used:				A									
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Volume	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Collected	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(L)	(ml)	Remarks
10	5	5	41	8	8	-0	10	6	48.2	1416	5.0		OLD BAG
25	21	21	43	8	16	-0	10	6	48.3	1206	4.3		OLD BAG
27	36	36	44	8	24	-0	10	6	48.1	1967	5.6		OLD BAG
30	1	1	57	8	32	-0	10	6	48.1	1949	5.5		OLD BAG
31	26	26	57	8	40	-0	10	6	48.2	2133	3.5		OLD BAG
32	34	34	58	8	48	-0	10	6	48.0	1413	5.8		OLD BAG
											4.95	AVG	
											0.8139	STD	
											5.8	MAX	
General Comments: The folding of the bags may be causing the											3.5	Min	
low sample volumes due to locking the bags into smaller													
bags. For the next cast we will try a different folding size.													
Increasing fold from 5.5" to 6.5" and lifting flaps.													
Folds are going to be made without overlapping.													

Altimeter Results of Cast B

Date: 17 April 1990		Water depth based on Ship's Fathometer				3981m
					Latitude	38°13.99'N
Altimeter	CTD				Water	Altimeter
Bottom(m)	Depth(db)	gr[1]	d[1]	Depth(m)[1]	Depth(m)[2]	Delta(m)[3]
1264	2769	10	26765	2730	3994	-1
1240	2790	10	26967	2751	3991	2
1203	2830	10	27351	2790	3993	0
1166	2860	10	27639	2819	3985	8
991	3044	10	29405	2999	3991	2
889	3150	10	30422	3103	3992	1
796	3250	10	31381	3201	3997	-4
693	3350	10	32340	3299	3992	1
350	3712	10	35806	3652	4002	-9
455	3600	10	34734	3543	3997	-5
684	3367	10	32503	3315	3999	-6
836	3200	10	30902	3152	3988	4
1026	3000	10	28983	2956	3983	10
1235	2800	10	27063	2761	3996	-3
1328	2700	10	26102	2663	3991	2
1427	2600	10	25141	2565	3991	2
1532	2500	10	24179	2467	3999	-6
1804	2200	10	21292	2172	3976	17
1950	2100	10	20329	2074	4024	-31
2027	2000	10	19365	1976	4002	-9
2201	1810	10	17533	1789	3990	3
2239	1767	10	17118	1746	3985	8
2409	1600	10	15506	1582	3991	2
2537	1460	10	14154	1444	3981	12
				Average	3993	
Notes:	[1] CTD depth computed in meters from pressure in decibars using Saunders and Fofnoff's method Deep Sea Research 1976,23,109-111					
	[2] Water Depth based on Altimeter Reading and CTD Depth					
	[3] Altimeter Delta using average water depth					

Cruise 219 NSF Water Sampler Cast Log													
Cast:	B				Date:	17-Apr-90			Time in:		8:40		
Battery Set Used:				A									
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Volume	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Collected	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(L)	(ml)	Remarks
1	3	3	2	8	8	-0	10	7.6	49.6	825	3.5		[1]
2	33	33			8	-0						16	[1]
3	35	35	4	8	16	-0	10	7.6	49.4	476	1.8		[1], leaky valve
4	27	27	6	8	24	-0	10	7.6	49.3	988	7.0		e
5	37A	37A	7	8	32	-0	10	7.6	49.2	314	6.0		[1]
6	16	16	8	16	48	-0	10	7.6	49.4		7.4		ran pump twice
7	15	15	21	8	56	-60	225	10.4		223	1.8		[1]
8	39	39	21	8	64	-60	241	10.1		416	0.0	5	
9	28	28	22	8	72	-60	267	9.5		178	6.5		[1]
10	5	5	22	8	80	-60	255	9.3		111	2.5		OLD BAG
11	23	23	22	8	88	-60	295	9.0		156	0.0	25	[1]
12	2	2	23	8	96	-60	309	8.5			0.0	40	[1]
13	17	17	23	8	104	-60	326	8.2	49.4	129	0.0	25	[1]
14	20	20			104	-60						80	[1]
15	7	7	33	8	112	-60	800	4.6	49.3	258	3.0		[1]
16	13	13	47	8	120	-60	1600	3.8	49.0	252	3.4		[1]
17	29	29	62	8	128	-60	2400	3.1	48.8	195	4.5		[1]
18	18	18			128	-60						70	
19	19	19	85	8	136	-30	3600	2.2	48.5	142	0.0	1	[1],[2]
20	32	32										40	
21	40	40										85	[1]
22	37	37										9	[1]
23	30	30										1	[1],[2]
24	4	4										22	[1]
25	21	21										8	OLD BAG
26	22	22										35	
27	36	36										10	OLD BAG
28	25	25										26	
29	10	10										15	
30	1	1										21	OLD BAG
31	26	26										20	OLD BAG
32	34	34										35	OLD BAG
33	38	38										11	
34	9	9										1	[2]
35	8	8										20	
36	31	31										45	
Notes:	[1] Refolded Bag												
	[2] Ridge around poppet												

Cruise 219 NSF Water Sampler Cast Log

Cast: D | **Date:** 18-Apr-90 | **Time in:** 21:15

Battery Set Used: B

Drawer Position	Inlet Valve Body	Pop.	Time in Water (min)	Pumping Time Drawer (sec)	Cumulative (sec)	Cast Speed (m/min)	UWU Depth (db)	Water Temp. (°C)	Battery Voltage (vdc)	Flow Reading	Volume Collected (L)	Volume Leaked (ml)	Remarks
Home			37	10	10	-0	1034	10.0	49.7	416			
1	40	40	37	10	20	-0	1034	10.0	50.0		0		
3	5	5	59	10	30	-0	2000		49.2	376	0		[1]
5	28	28		10	40	-0	2516		49.0	666	1.3		[1]
7	34	34		10	50	-0	3013		48.9	279	0		[1]
9	9	9		10	60	-0	3514		48.6	382	0		
11	25	25		10	70	-0	4007	2.3	48.2	328	0		[1]
13	37	37	116	10	80	-0	4504		48.4	325	0		[1]
15	37A	37A		20	100	-0	4504		48.4	-27452	0.8		
17	22	22		10	110	-0	4504		48.3	280	1.5		[2]
19	23	23		10	120	+0	4504		48.2	424	0		
21	39	39		20	140	+0	4504		48.2	588	0		
23	15	15		30	170	+0	4504		48.0	965	0		
25	3	3		10	180	+0	4012	2.3	48.0	304	1		
27	31	31		10	190	+0	3513		48.0	491	0		[1]
29	21	21	171	10	200	+0	3014		48.0	282	1.2		[1]
31	33	33		10	210	+0	2517		48.0	411	0		[1]
33	38	38		10	220	+0	2019		47.8	100	0		[1]
35	19	19		10	230	+0	1021	10.0	47.7	690	0		[1]

Notes

[1] No Screw in threaded hole for use with extraction probe

[2] Valve held open with 3 nylon washers which were still in place after pumping

Altimeter Results of Cast C

Date: 18 April 1990		Water depth based on Ship's Fathometer				5004 m
					Latitude	36°15.06'N
Altimeter	CTD				Water	Altimeter
Bottom(m)	Depth(db)	gr[1]	d[1]	Depth(m)[1]	Depth(m)[2]	Delta(m)[3]
2149	2800	10	27063	2761	4910	20
1248	3700	10	35691	3641	4889	41
1130	3877	10	37384	3814	4944	-14
1020	3988	10	38446	3922	4942	-12
901	4112	10	39630	4043	4944	-14
1029	3969	10	38264	3903	4932	-2
1204	3777	10	36428	3716	4920	10
1348	3639	10	35108	3582	4930	0
1420	3575	10	34495	3519	4939	-9
1505	3488	10	33662	3434	4939	-9
1555	3439	10	33193	3386	4941	-11
				Average	4930	
Notes:	[1] CTD depth computed in meters from pressure in decibars using Saunders and Fofnoff's method Deep Sea Research 1976,23,109-111					
	[2] Water Depth based on Altimeter Reading and CTD Depth					
	[3] Altimeter Delta using average water depth					

Cruise 219 NSF Water Sampler Cast Log													
Cast:	D4				Date:	19-Apr-90			Time in:		14:50		
Battery Set Used:				B									
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Volume	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Collected	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(L)	(ml)	Remarks
0	0	0	54	10	10		3000		49.3	138			[1]
16	18	40		10	20	-0	3000		49.2	157	1.5		[1]
13	19	23		10	30	-0	3000		49.2	228	0.0		[1]
17	5	31		10	40	-0	3000		49.2	93	0.0		[1]
29	3	34		10	50	-0	3000		49.2	72	3.1		[1]
33	32	39		10	60	-0	3000		49.1	155	0.2		[1]
0	0	0	84	10	70	+0	2000		48.9	160			[1]
28	37	25		10	80	+0	2000		48.9	135	0.3		[1]
1	29	21		10	90	+0	2000		48.9	242	2.5		[1]
2	6	38		10	100	+0	2000		49.0	330	0.0		[1]
14	8	22		10	110	+0	2000		49.0	271	0.5		[1]
18	27	5		10	120	+0	2000		48.9	232	0.0		[1]
0	0	0	105	10	130	+0	1000		48.7	287			[1]
8	34	3		10	140	+0	1000		48.8	183	7.5		[1]
12	38	9		10	150	+0	1000		48.8	258	0.0		[1]
32	1	37		10	160	+0	1000		48.7	446	1.5		[1]
Notes:	[1] Taped top front of each drawer. Added Skirt to Rotary Valve pump												
	inlet. Modified flowmeter flange to allow tighter seal.												

Cruise 219 NSF Water Sampler Cast Log

Cast: D1 **Date:** 19-Apr-90 **Time in:** 8:55

Battery Set Used: B

Drawer Position	Inlet Body	Valve Pop.	Time in Water (min)	Pumping Time Drawer (sec)	Pumping Time Cumulative (sec)	Cast Speed (m/min)	UWU Depth (db)	Water Temp. (°C)	Battery Voltage (vdc)	Flow Reading	Volume Collected (L)	Volume Leaked (ml)	Remarks
0				10	10				47.54	639			
8	34	3		10	20	-0	10	19.5	47.55	673	6.5		
12	38	9		10	30	-0	10	19.5	47.5	720	6.8		
16	18	40		10	40	-0	10	19.5	47.54	358	7.5		
28	37	25		10	50	-0	10	19.5	47.46	636	6.8		loose poppet gasket
32	1	37		10	60	-0	10	19.5	47.55	894	7.5		

Cruise 219 NSF Water Sampler Cast Log

Cast: D2 **Date:** 19-Apr-90 **Time in:** 10:50

Battery Set Used: B

Drawer Position	Inlet Body	Valve Pop.	Time in Water (min)	Pumping Time Drawer (sec)	Pumping Time Cumulative (sec)	Cast Speed (m/min)	UWU Depth (db)	Water Temp. (°C)	Battery Voltage (vdc)	Flow Reading	Volume Collected (L)	Volume Leaked (ml)	Remarks
0				10	10				49.8	224			
8	34	3		10	20	0	500	17.6	48.8	168	7.6		
12	38	9		10	30	0	500	17.6	49.7	187	0.0		
16	18	40		10	40	0	500	17.6	49.8	219	7.2		
28	37	25		10	50	0	500	17.6	49.6	204	7.6		
32	1	37		10	60	0	500	17.6	49.7	-98	7.4		

Cruise 219 NSF Water Sampler Cast Log

Cast: D3 **Date:** 19-Apr-90 **Time in:** 12:30

Battery Set Used: B

Drawer Position	Inlet Body	Valve Pop.	Time in Water (min)	Pumping Time Drawer (sec)	Pumping Time Cumulative (sec)	Cast Speed (m/min)	UWU Depth (db)	Water Temp. (°C)	Battery Voltage (vdc)	Flow Reading	Volume Collected (L)	Volume Leaked (ml)	Remarks
0				10	10				49.6	166			
8	34	3	23	10	20	0	1200		49.6	181	7.4		
12	38	9		10	30	0	1200		49.5	167	0.0		
16	18	40		10	40	0	1200		49.5	185	7.2		
28	37	25		10	50	0	1200		49.4	175	7.5		
32	1	37		10	60	0	1200		49.5	104	6.3		
1	29	21		10	70	0	1200		49.4	113	7.0		
13	19	23		10	80	0	1200		49.4	180	7.0		

Cruise 219 NSF Water Sampler Cast Log

Cast:	E				Date:	19-Apr-90				Time in:	19:20		
Battery Set Used:				B									
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Volume	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Collected	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(L)	(ml)	Remarks
8	20	20		10	10	-0	10	19.75	49.45	308	7.5		
12	2	2		10	20	-0	10	19.75	49.72		7.2		
16	16	16		10	30	-0	10	19.75	49.5	162	7		
28	18	18		10	40	-0	10	19.75	49.51		6.5		
32	1	1		10	50	-0	10	19.75		181	7.4		
1	37	37		10	60	-0	500	17.52	49.28	161	7.5		
13	21	21		10	70	-0	500	17.52	49.67		6.8		[1]
2	30	30		10	80	-30	800	13.24	48.89	163	7		
14	17	17		10	90	-30	825	12.7	49.15	245	0		
18	10	10		10	100	-30	850	12.15	48.86	276	6.5		
34	22	22		10	110	-30	875	11.47	48.84	189	6.5		
4	13	13		10	120	-30	900	10.79	49.12		5.5		
5	28	28		10	130	-0	1200	5.8	48.64	149	7.3		
9	38	38		10	140	-0	1200	5.8	48.89	86	6.5		
21	39	39		10	150	-0	2000	3.93	48.64	186	6		
25	23	23		10	160	-0	2000	3.93	48.65		6.2		[1]
7	22	22		10	170	-0	2700	3.39	48.52	467	0.2		
20	26	26		10	180	-60	2800	3.28	48.46	519	0		
11	5	5		10	190	-0	3100	2.99	48.37	593	3		
24	35	35		10	200	-60	3200	2.9	48.35	548	1.1		
27	33	33		10	210	-0	3500	2.63	48.29	262	0.1		
36	7	7		10	220	-60	3600	2.55	48.21	420	1.1		
31	3	3		10	230	-0	3900	2.38	48.38		1.5		[2]
6	32	32		10	240	-60	4000	2.34	48.16	376	1.5		[1]
17	40	40		10	250	+0	3900	2.38	48.08	188	0.3		
29	25	25		10	260	+0	3500	2.62	47.98	9831	0.1		
33	15	15		10	270	+0	3100	2.98	47.92	960	0		
3	37A	37A		10	280	+0	2700	3.37	47.85	383	1.1		
15	9	9		10	290	+0	1200	5.91	47.77	343	1		[1]
19	19	19		10	300	+0	1200	5.91	47.76	491	5.4		
10	27	27		10	310	30	900	11.34		560	7		
22	8	8		10	320	30	866	12.03		493	5.2		
26	4	4		10	330	30	833	12.72		306	0		
30	29	29		10	340	30	800	13.41	47.55	354	5.5		
23	31	31		10	350	0	10	19.79	47.5	246	7.5		[1]
35	34	34		10	360	0	10	19.79	47.38	130	7.4		

Notes: [1] a 1/8" gasket was added to back of drawer.

[2] at 3650 m rotary valve stuck, stopped winch and was able to worked it free.

Cruise 219 NSF Water Sampler Cast Log														
Cast:	F					Date:	20-Apr-90			Time in:	16:28			
Battery Set Used:				B										
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Volume	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Collected	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(L)	(ml)	Remarks
27	9	9	0	5	5	0	0	19.5	50.2	70	5.0		
31	4	4	0	5	10	0	0	19.5			6.0		
8	3	3	18	5	15	0	1200	6.0		40	3.1		
12	40	40	18	10	25	0	1200	6.0		53	7.6		
16	23	23	20	5	30	0	1200	6.0		42	7.2		
28	22	22	20	10	40	0	1200	6.0		63	7.3		
32	21	21	22	5	45	0	1200	6.0		49	6.2		
1	33	33	22	10	55	0	1200	6.0		110	7.3		
13	28	28	26	5	60	0	1200	6.0		38	5.4		
17	34	34	26	10	70	0	1200	6.0		64	4.5		Has hole bottom seam
29	25	25	34	5	75	0	1200	6.0		38	8.0		
33	38	38	34	10	85	0	1200	6.0		110	7.4		
2	19	19	50	5	90	0	1200	6.0		41	2.0		
14	31	31	50	10	100	0	1200	6.0		97	7.0		
18	37	37	84	5	105	0	1200	6.0		18	1.3		
34	39	39	84	10	115	0	1200	6.0		62	6.6		
3	15	15	108	5	120	0	1200	6.0			0.0		
15	17	17	108	10	130	0	1200	6.0			0.0		

Cruise 219 NSF Water Sampler Cast Log

Cast:	G					Date:	20-Apr-90			Time in:	21:27		
Battery Set Used:				B									
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Volume	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Collected	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(L)	(ml)	Remarks
0			3	10	10		10	19.8	50.0	324			
8	26	26		10	20	-0	10	19.8		210	0.0	1	[1],[2]
12	35	35		10	30	-0	10	19.8		134	5.1		[3]
16	32	32		10	40	-0	10	19.8		132	7.2		
28	7	7		10	50	-0	10	19.8		132	7.2		
32	13	13		10	60	-0	10	19.8			7.0		[4]
1	20	20		10	70	-30	750	13.5		298	0.0	1	
13	18	18		10	80	-30	775	12.9		134	6.7		[3]
17	16	16		10	90	-30	800	12.3		115	5.9		[3]
29	10	10		10	100	-30	850	11.3	49.7	131	7.2		
33	9	9		10	110	-30	1950	4.1		101	6.2		[8]
2	37	37		10	120	-30	2000	4.0		55	6.0		
14	19	19		10	130	-30	2050	4.0	49.5	105	6.5		
18	28	28		10	140	-30	2900	3.1		50	3.0		
34	4	4		10	150	-30	3000	3.0		54	0.0	90	[6]
3	3	3		10	160	-30	3100	2.9	49.0	26	3.5		
15	25	25	78	10	170	-0	4000	2.4	49.0	25	0.7		[6]
19	23	23	88	10	180	-0	4000	2.4		19	0.2		
23	40	40	98	10	190	-0	4000	2.4		51	6.9		
35	22	22	108	10	200	+0	4000	2.4	48.9	19	0.0		
4	34	34	118	10	210	+0	4000	2.4		20	1.6		
20	1	1	128	10	220	+0	4000	2.4	48.7	12	0.0	100	[6],[7]
24	14	14		10	230	30	3100	3.0		32	0.0	36	
36	30	30		10	240	30	3000	3.0		37	1.8		
5	29	29		10	250	30	2900	3.1		50	2.4		
9	27	27		10	260	30	2050	3.9	48.7	72	0.0	13	
21	36	36		10	270	30	2000	3.9		189	0.0	1	[2]
25	21	21		10	280	30	1950	3.9	48.5	69	4.0		
6	39	39		10	290	0	1200	5.7		64	5.8		
10	31	31		10	300	0	1200	5.7		53	7.1		
22	38	38		10	310	0	1200	5.7		109	0.0	150	[6]
26	33	33		10	320	0	1200	5.7		59	6.6		
30	8	8		20	340	30	850	11.5			5.7		
7	2	2		10	350	30	800	12.4		144	6.2		[3]
11	37A	37A		10	360	30	775	12.8	48.0	82	3.6		[3]
27	15	15		10	370	0	10	19.6		161	7.0		
31	17	17	218	10	380	0	10	19.6	47.9	179	7.4		0505GMT
Notes:	[1] Missing one fastener						[5] Drawer Broken						
	[2] Bag ridge around poppet						[6] Measured Volume after cutting open						
	[3] Leaking valve						[7] Rotary Valve sticks here						
	[4] Brust Bag, Volume Estimated based on shape						[8] Defective magnet						

Cruise 219 NSF Water Sampler Cast Log													
Cast:	H				Date:	21-Apr-90				Time in:	not recorded		
Battery Set Used:				not recorded									
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Cracking	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Pressure	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(psi)[3]	(ml)[4]	Remarks
1	17	17					5				1.0	2.2	[2]
2	3	3					5				1.0	7.0	[1]
3	21	21					5				6.5	1.0	[2]
4	13	13					5				4.5	1.0	[1]
5	40	40					5				1.0	10.0	[2]
6	29	29					5				2.0	1.0	[1]
7	2	2					5				1.0	3.0	[2]
8	28	28					5				1.0	1.6	[1]
9	9	9					5				4.8	3.0	[2]
10	19	19					5				5.8	0.0	[2]
14	15	15					5				5.5	0.0	[1]
15	32	32					5				5.5	1.0	[1]
Notes:	[1] Full taping used to hold bag to valve body												
	[2] 3.6" Dia Circle tape used to hold bag to valve body												
	[3] Cracking is pressure (psi) to leak water												
	[4] Volume of water found in bags												
	The water sampler was push over to its side												
		during launch											

Cruise 219 NSF Water Sampler Cast Log													
Cast:	I				Date:	21-Apr-90				Time in:	not recorded		
Battery Set Used:				not recorded									
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Cracking	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Pressure	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(psi)[3]	(ml)[4]	Remarks
36	22						10				6.0	1	[2]
29	36						10				7.0	0	[1]
35	1						10				6.5	1	[1]
34	8						10				0.5	13	[2]
23	16						10				0.5	17	[1]
30	10						10				5.9	1	[2]
24	31						10				4.8	2	[2]
31	4						10				5.5	1	[1]
25	33						10				5.5	1	[1]
32	20						10				1.5	3	[2]
26	18						10				0.5	10	[2]
33	14						10				1.5	1	[1]
Notes:	[1] Full taping used to hold bag to valve body												
	[2] 3.6" Dia Circle tape used to hold bag to valve body												
	[3] Cracking is pressure (psi) to leak water												
	[4] Volume of water found in bags												

Cruise 219 NSF Water Sampler Cast Log													
Cast:	J				Date:	21-Apr-90			Time in:		not recorded		
Battery Set Used:				not recorded									
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Cracking	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Pressure	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(psi)[3]	(ml)[4]	Remarks
29	2	2					1000				0.5	52	[1]
36	25	25					1000				6.0	26	[1]
28	32	32					1000				4.5	1	[1],[7]
35	38	38					1000				6.5	23	[1]
27	21	21					1000				7.0	10	[2]
34	22	22					1000				5.5	10	[1]
26	9	9					1000				7.0	14	[2]
33	36	36					1000				6.7	48	[1]
25	1	1					1000				6.0	160	[2],[5],[6]
32	19	19					1000				5.2	1	[2],[7]
24	15	15					1000				6.0	1	[2],[7]
31	27	27					1000				6.5	28	[2]
Notes:	[1] Full taping used to hold bag to valve body												
	[2] 3.6" Dia Circle tape used to hold bag to valve body												
	[3] Cracking is pressure (psi) to leak water												
	[4] Volume of water found in bags												
	[5] Measurement resulted in Salinity of 36.617/surface of 36.551												
	[6] bag was not pressed well (wrinkled)												
	[7] bag ridge around Poppet												

Cruise 219 NSF Water Sampler Cast Log

Cast:	K					Date:	28-Apr-90			Time in:	not recorded		
Battery Set Used:				not recorded									
Drawer Position	Inlet Body	Valve Pop.	Time in Water (min)	Pumping Time Drawer (sec)	Pumping Time Cumulative (sec)	Cast Speed (m/min)	UWU Depth (db)	Water Temp. (°C)	Battery Voltage (vdc)	Vacuum (torr)[1]	Cracking Pressure (psi)[2]	Volume Leaked (ml)[3]	Remarks
20	50						20			8.3		0.4	
36	51						20			22.4		2.6	
9	52						20			28.5		8.6	
34	53						20			27.0		8.0	
10	54						20			11.7		4.0	
30	55						20			4.7		0.1	
3	56						20			4.2		0.3	
12	57						20			12.0		1.2	
18	58						20			21.2		12.0	
23	59						20			13.4		0.4	
26	61						20			11.8		1.5	
6	64						20			12.3		0.4	
8	65						20			12.5		1.0	
21	66						20			5.1		0.2	
11	67						20			15.5		3.6	
35	68						20			19.0		0.8	
28	69						20			14.2		2.5	
1	70						20			10.3		0.9	
24	71						20			19.4		5.6	
15	72						20			9.2		0.4	
14	73						20			1.8		0.1	
33	74						20			15.3		4.4	
4	75						20			9.4		1.0	
13	76						20			4.2		0.1	
5	77						20			11.4		1.2	
27	78						20			5.3		0.4	
7	79						20			17.0		2.3	
31	80						20			4.2		0.4	
2	81						20			8.4		1.0	
17	82						20			10.4		1.1	
29	83						20			18.5		1.8	
25	84						20			7.0		0.1	
16	85						20			20.0		1.2	
32	86						20			17.6		0.8	
22	87						20			15.0		8.0	
19	88						20			12.1		1.8	
Notes:	[1] Vacuum level bag was evacuated												
	[2] Cracking is pressure (psi) to leak water												
	[3] Volume of water found in bags												

Cruise 219 NSF Water Sampler Cast Log

Cast: L | **Date:** 29-Apr-90 | **Time in:** not recorded

Battery Set Used: not recorded

Drawer Position	Inlet Valve Body	Inlet Valve Pop.	Time in Water (min)	Pumping Time Drawer (sec)	Pumping Time Cumulative (sec)	Cast Speed (m/min)	UWU Depth (db)	Water Temp. (°C)	Battery Voltage (vdc)	Vacuum (torr)[1]	Cracking Pressure (psi)[2]	Volume Leaked (ml)[3]	Remarks
1	83						5000			4.40		5.7	
2	59						5000			1.32		1.2	
3	63						5000			3.58		1.6	
4	56						5000			8.90		5.0	
5	87						5000			5.50		4.2	
6	66						5000			4.25		4.8	
7	57						5000			2.93		2.1	
8	64						5000			7.25		4.7	
9	84						5000			3.26			not recorded
10	70						5000			2.60		0.9	
11	58						5000			7.95		6.0	
12	74						5000			7.90		3.4	
13	77						5000			3.16		1.2	
14	53						5000			9.90		5.6	
15	79						5000			3.42		1.8	
16	52						5000			1.38		0.1	
17	71						5000			4.47		2.4	
18	65						5000			3.30		2.4	
19	62						5000			2.10		0.4	
20	61						5000			6.00		5.5	
21	50						5000			6.15		4.6	
22	80						5000			5.47		0.9	
23	81						5000			2.09		0.1	
24	76						5000			5.95		3.4	
25	78						5000			6.03		5.6	
26	75						5000			5.95		3.0	
27	69						5000			4.52		2.6	
28	72						5000			1.68		0.2	
29	55						5000			1.69		0.2	
30	85						5000			1.87		0.2	
31	51						5000			2.82		1.0	
32	88						5000			4.97		4.2	
33	73						5000			3.60		1.2	
34	86						5000			6.35		4.4	
35	67						5000			2.56		0.5	
36	68						5000			2.64		1.5	

Notes: [1] Vacuum level bag was evacuated
[2] Cracking is pressure (psi) to leak water
[3] Volume of water found in bags

Altimeter Results of Cast L

Date: 29 April 1990		Water depth based on Ship's Fathometer				5111m
					Latitude	33°49.32'N
Altimeter	CTD				Water	Altimeter
Bottom(m)	Depth(db)	gr[1]	d[1]	Depth(m)[1]	Depth(m)[2]	delta(m)[3]
1099	3910	10	37704	3847	4946	105
940	4138	10	39874	4068	5009	42
946	4358	10	41974	4283	5229	-178
811	4480	10	43142	4402	5213	-162
528	4589	10	44184	4508	5036	15
467	4657	10	44828	4574	5041	10
394	4725	10	45474	4639	5034	17
359	4765	10	45858	4679	5038	13
308	4822	10	46400	4734	5041	9
243	4887	10	47018	4797	5040	11
218	4921	10	47345	4830	5048	3
164	4967	10	47782	4875	5039	12
85	5053	10	48600	4958	5044	7
110	5028	10	48364	4934	5045	6
234	4903	10	47176	4813	5047	4
322	4819	10	46375	4731	5053	-2
431	4697	10	45211	4613	5043	8
485	4647	10	44736	4564	5049	2
527	4597	10	44254	4515	5042	9
620	4504	10	43373	4425	5046	5
714	4400	10	42376	4324	5038	13
849	4292	10	41345	4218	5067	-17
871	4245	10	40901	4173	5044	7
942	4166	10	40147	4096	5038	13
1116	3979	10	38356	3914	5030	21
1443	3659	10	35301	3602	5045	5
1513	3580	10	34546	3525	5038	13
1629	3463	10	33419	3410	5039	12
1714	3371	10	32537	3320	5034	16
1823	3265	10	31528	3217	5040	11
1938	3150	10	30420	3104	5042	9
2110	2976	10	28753	2934	5044	7
2356	2729	10	26378	2692	5048	3
2505	2574	10	24894	2540	5045	5
2617	2464	10	23831	2432	5049	2
2734	2352	10	22755	2322	5056	-5
2943	2141	10	20723	2115	5058	-7
3051	2050	10	19851	2026	5077	-26
3131	1958	10	18960	1935	5066	-15
				Average	5051	
Notes:	[1] CTD depth computed in meters from pressure in decibars using Saunders and Fofnoff's method Deep Sea Research 1976,23,109-111					
	[2] Water Depth based on Altimeter Reading and CTD Depth					
	[3] Altimeter Delta using average water depth					

Cruise 219 NSF Water Sampler Cast Log													
Cast:	**M**					**Date:**	**30-Apr-90**			**Time in:**	**not recorded**		
Battery Set Used:			**not recorded**										
			Time in	**Pumping Time**		**Cast**	**UWU**	**Water**	**Battery**		**Cracking**	**Volume**	
Drawer	**Inlet Valve**		**Water**	**Drawer**	**Cumulative**	**Speed**	**Depth**	**Temp.**	**Voltage**	**Vacuum**	**Pressure**	**Leaked**	
Position	**Body**	**Pop.**	**(min)**	**(sec)**	**(sec)**	**(m/min)**	**(db)**	**(°C)**	**(vdc)**	**(torr)**	**(psi)**	**(ml)**	**Remarks**
11	55	55					926						[2]
14	53	53					926			4		1.2	
17	79	79					926			2		4.7	
19	52	52					926						[1]
22	62	62					926			3		3.3	
23	81	81					926			5		6.5	
25	85	85					926						[2]
28	70	70					926						[2]
31	72	72					926						[2]
34	51	51					926						[2]
Notes:	[1] Collected Water												
	[2] Pumped, but didn't collect water												

Altimeter Results of Cast M						
Date: 30 April 1990		Water depth based on Ship's Fathometer				5111 m
					Latitude	33°49.32'N
Altimeter	CTD				Water	Altimeter
Bottom(m)	Depth(db)	gr[1]	d[1]	Depth(m)[1]	Depth(m)[2]	delta(m)[3]
1299	3788	10	36531	3728	5026	22
1049	4039	10	38928	3972	5021	27
742	4378	10	42173	4303	5045	3
423	4707	10	45307	4622	5045	3
144	5012	10	48215	4919	5063	-15
333	4813	10	46317	4725	5058	-10
484	4653	10	44792	4570	5053	-6
698	4435	10	42715	4358	5056	-8
1099	4025	10	38803	3959	5058	-11
1740	3362	10	32454	3312	5051	-4
				Average	5048	
Notes:	[1] CTD depth computed in meters from pressure in decibars using Saunders and Fofnoff's method Deep Sea Research 1976,23,109-111					
	[2] Water Depth based on Altimeter Reading and CTD Depth					
	[3] Altimeter Delta using average water depth					

Cruise 219 NSF Water Sampler Cast Log

Cast:	N					Date:	30-Apr-90		Time in:		not recorded		
Battery Set Used:			not recorded										
			Time in	Pumping Time		Cast	UWU	Water	Battery		Cracking	Volume	
Drawer	Inlet	Valve	Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Vacuum	Pressure	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)	(torr)	(psi)	(ml)	Remarks
16	51	51					400						[2,3]
19	55	55					100						[2,4]
17	70	70					300						[2,3]
21	72	72					20						[1,3]
18	85	85					200						[2,3]
Notes:	[1] Collected Water												
	[2] Pumped, but didn't collect water												
	[3] Drawer Broken from Pumping												
	[4] Drawer Lid caved in												

Cruise 219 NSF Water Sampler Cast Log

Cast:	O					Date:	30-Apr-90		Time in:		23:53	GMT	
Battery Set Used:			not recorded										
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Volume	Volume	
Drawer	Inlet	Valve	Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Collected	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(L)	(ml)	Remarks
Home				10	10		5006		49.8	20528			[7]
22	57	57										95.0	[5]
30	74	74		10	20		5006		49.8	4627		1.5	[2]
31	70	70		10	30		4297		49.4	0		1.5	[2]
32	69	69		10	40		4257			21946		100.0	[2,5]
33	62	62		10	50		4207		49.3	37	4.8		[1,6]
34	51	51		10	60		4159		49.3	25	6.4		[1,6]
35	85	85		10	70		4108		49.4	19722		0.5	[2]
36	72	72		10	80		4058		49.4	21144		60.0	[2,5]
17	63	63										50.0	[5]
16	67	67										1.5	
21	73	73										2.5	
Notes:	[1] Collected Water												
	[2] Pumped, but didn't collect water												
	[3] Drawer Broken from Pumping												
	[4] Drawer Lid caved in												
	[5] No Poppet Gasket												
	[6] Poppet Gasket on OD												
	[7] Bags evacuated and back filled to 1 atm with nitrogen												

Cruise 219 NSF Water Sampler Cast Log													
Cast:	P				Date:	1-May-90			Time in:		not recorded		
Battery Set Used:				not recorded									
			Time in	Pumping Time		Cast	UWU	Water	Battery	Flow	Volume	Volume	
Drawer	Inlet Valve		Water	Drawer	Cumulative	Speed	Depth	Temp.	Voltage	Reading	Collected	Leaked	
Position	Body	Pop.	(min)	(sec)	(sec)	(m/min)	(db)	(°C)	(vdc)		(L)	(ml)	Remarks
Home				10	10				48.8	0			[10]
1	65			10	20		3454		48.5	2			[1,6]
2	59			10	30		3433		48.5	3			[1,6]
3	73			10	40		3408		48.5	-25778			[2,6,8]
4	68			10	50		2996		48.5				[1,6]
5	70			10	60		2496		48.4	8			[1,6]
6	71			10	70		2001		48.1	7			[1,6]
7	75			10	80		1499		48.1	20			[1,6]
8	80			10	90		1000		47.8	51			[1,6]
9	86			10	100		495		48.0	96			[1,6]
10	88			10	110		58		48.1	7			[1,6]
11	50											14.2	[6]
17	56											25	[6]
18	57												[6,9]
24	62											16.8	[6]
25	63											8.7	[6]
14	64											6	[6]
15	67											9.2	[6]
21	74											12	[6]
22	76											32.8	[6]
29	85											136	[6]
Notes:	[1] Collected Water												
	[2] Pumped, but didn't collect water												
	[3] Drawer Broken from Pumping												
	[4] Drawer Lid caved in												
	[5] No Poppet Gasket												
	[6] Poppet Gasket on OD												
	[7] Bags evacuated and back filled to 1 atm with nitrogen												
	[8] Bag heat sealed around poppet due to heat treatment												
	[9] Hole in bag												
	[10] Bags evacuated and back filled to 1/2 atm with nitrogen												

D: Handling and Deck Stowage System

Safe and effective operation of the integrated seawater sampler and data acquisition system is highly dependent upon the handling system to be used for underwater unit launch and recovery, vertical profiling operations, and on-deck stowage during transit. Based upon the operational requirements of WOCE and known limitations of existing handling systems, a conceptual design of the handling and deck stowage system was developed during Phase I; the design objectives of this system are listed below:

- Minimize risk of injury to on-deck personnel and equipment, especially during adverse sea conditions.
- Allow for straightforward installation on a variety of oceanographic research vessels with few, if any, modifications to the vessel's hull or deck equipment.
- Utilize winches, cables, and power systems that exist on UNOLS vessels.
- Operate as an integrated system, allowing control from the computer software package and minimizing the requiarement for manual interaction from the winch operator, except during launch and recovery.
- Allow safe stowage of the underwater unit during on-deck water sample transfer and transit stations.

As illustrated in Fig. D-1, this system consists of a CTD winch, a motion compensator, and a launch/recovery system with an on-deck stowage platform.

Launch/Recovery and Stowage Subsystem

During Phase *I, a conceptual design for the Launch/Recovery and Stowage System conceptual design was developed to:

- Provide a portable, self-contained launch/recovery system and a platform for on-deck stowage.
- Permit safe and effective handling and stowage of the underwater unit.
- Minimize pendulum motion of the underwater unit when out of the water during launch and recovery, and thus eliminate the ned for handling lines and reduce the number of personnel on deck.
- Allow safe profiling operations to continue during rough seas.

This system will save considerable time during overboard handling operations, especially in rough weather, but more importantly it will ensure greater safety to personnel and the underwater unit.

The approach followed in the conceptual design was to draw from existing techniques for the launching and recovery of heavy objects such as submersibles and remotely operated vehicles, and to incorporate readily available commercial components wherever feasible. This approach takes advantage of experience and tends to reduce cost.

The conceptual launch/recovery/stowage system is an integrated package that mounts to ship decks using the UNOLS standard 2 feet-on-center deck tie down points. The overall footprint is 8 feet in the athwartship direction and 11 feet in the fore-aft direction. The estimated weight of the system is 8,000 pounds. The system is depicted in Fig. D-2. The main components of the launch/recovery and stowage subsystem are:

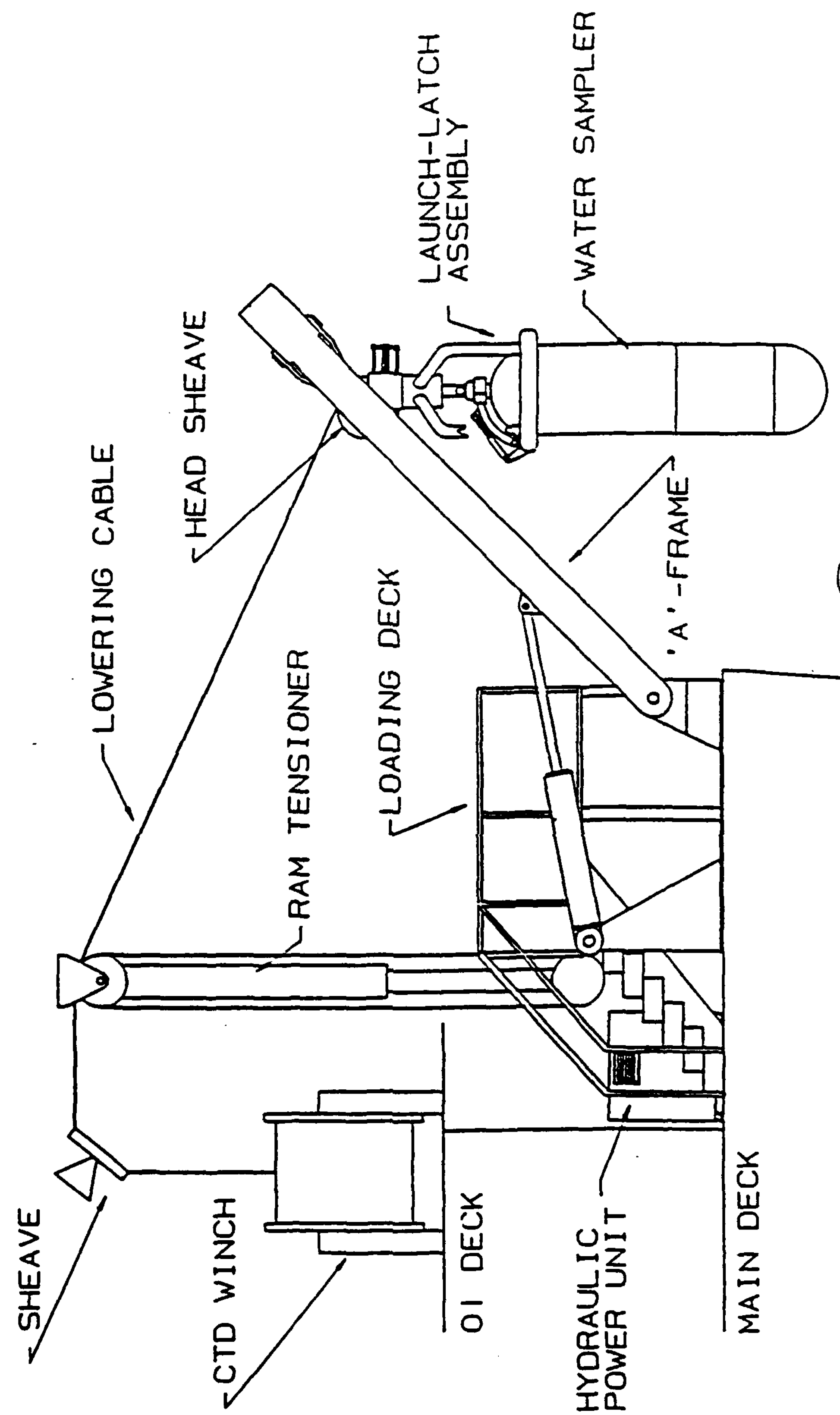


Figure D-1: Handling and Deck Stowage System

- A hydraulically actuated A-frame, 19 feet tall and 22 feet wide. The A-frame travels a total of 65 degrees and in its deployment position the centerline is 45 degrees from the vertical.

- A rack and pinion hydraulic rotary actuator is rigidly attached to the A-frame. The actuator supports the head sheave assembly and the receiving frame. The actuator allows the head sheave to follow the fore-aft cable angle during casts and also controls the fore-aft component of the pendulum motion that may occur during launch and recovery.

- A Head Sheave Assembly is attached to the pinion shaft of the fore-aft rotary actuator. This assembly provides support for the sheave hub and an attachment point for the athwartship rotary actuators.

- Mounted athwartship to the head sheave assembly are two additional rack and pinion rotary actuators. These additional actuators lock the receiving frame in its up position away from the cable, for normal profiling operations. They also control the athwartship component of the pendulum motion that may occur during launch and recovery.

- A receiving frame consisting of three locking arms and a 330-degree ring are supported by the athwart ship actuators. The locking arms are a spring/hydraulic mechanism. The spring forces the arms to their default position. In this position the three arms form a locking collar at the center of the receiving cage. The hydraulic cylinders are used to overcome the spring forces and to open the locking collar. in the event of hydraulic failure the arms return to the default position.

- The prime mover for the hydraulics, a 30 hp, 3-phase, 480 volt electric motor. The power pack also includes a 10 gallon reservoir, valves, filter, and a variable displacement pressure compensating hydraulic pump operating at a maximum pressure of 3,000 psi. This hydraulic pack is capable of moving the A-frame from the deployment position to the stowage position within 15 seconds.

- An on-deck stowage platform. The aluminum, frame and fiberglass decking provide a safe platform for loading and unloading the samples and permit easy access to the lower section of the underwater unit.

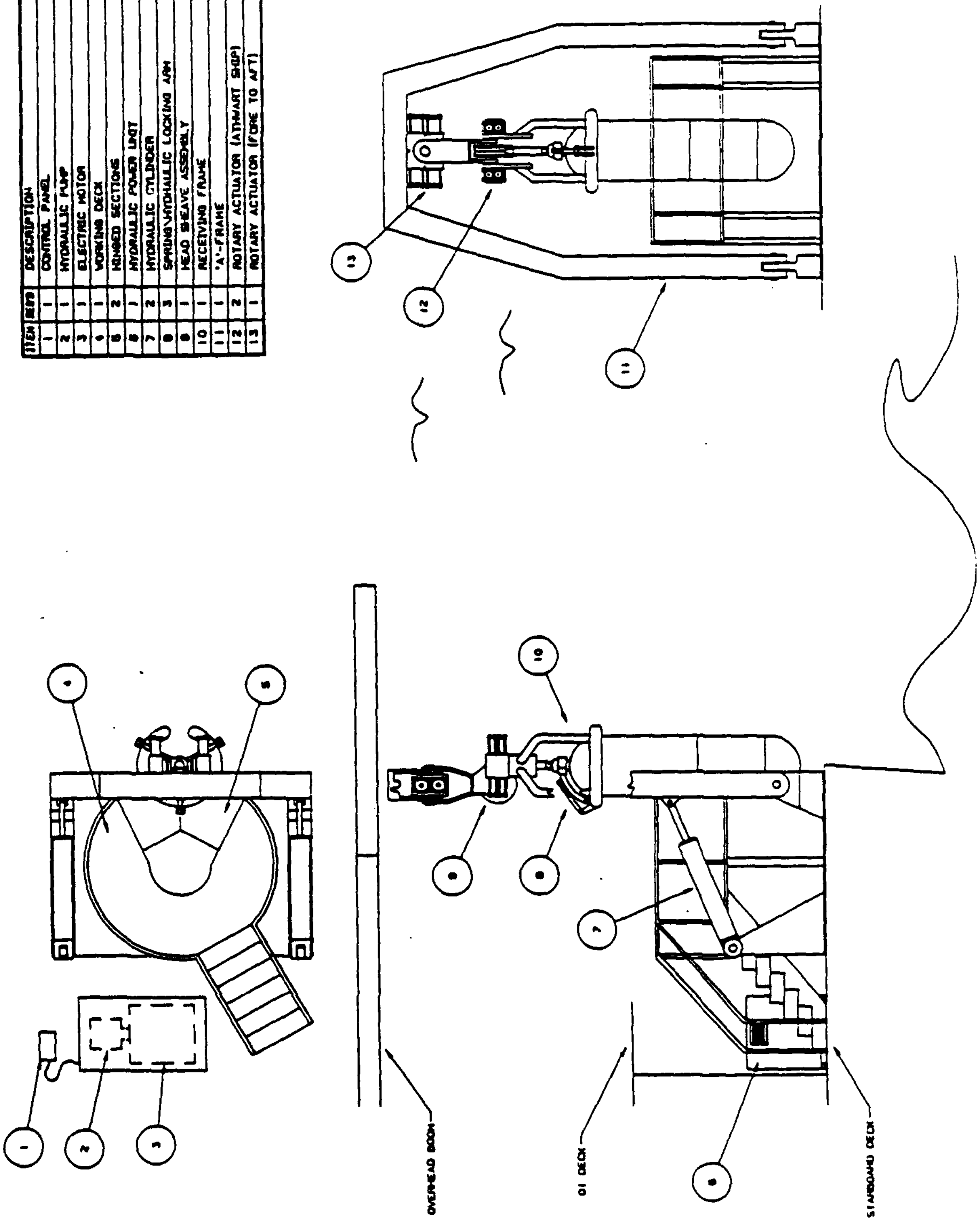
- An operator control panel with hydraulic control valves for A-frame manipulation, motion control of the launch-latch assembly, and activation of the locking mechanism. The launch and recovery is controlled by a human operator, not the computer.

Hydraulic Control Valve System

Fig. D-3 is a schematic representation of the hydraulic control for the launch/recovery handling system. The launch/recovery user control panel is also shown. The user has direct control of four sets of hydraulic actuators: A-frame position; fore-aft position; athwartship position; and opening of the locking collar. The operator also controls the swaying motion of the underwater unit by adjustment of three variable orifice valves. The hydraulic system is protected from over pressure by three cross-over relief valves. The A-frame actuators will be equipped with counterbalance and lock valves to prevent control loss.

Fig. D-4 illustrates the four-step procedure for launch/recovery of the underwater unit, as described below:

1. The winch operator first provides slack to the lowering cable. The platform deck doors are then lifted and the outboard section of the handrail is retracted.



ITEM	REQD	DESCRIPTION
1	1	CONTROL PANEL
2	1	HYDRAULIC PUMP
3	1	ELECTRIC MOTOR
4	1	WORKING DECK
5	2	HINGED SECTIONS
6	1	HYDRAULIC POWER UNIT
7	2	HYDRAULIC CYLINDER
8	3	SPRING\HYDRAULIC LOCKING ARM
9	1	HEAD SHEAVE ASSEMBLY
10	1	RECEIVING FRAME
11	1	'A'-FRAME
12	2	ROTARY ACTUATOR (ATHWART SHIP)
13	1	ROTARY ACTUATOR (FORE TO AFT)

Figure D-2: Launch/Recovery Stowage System

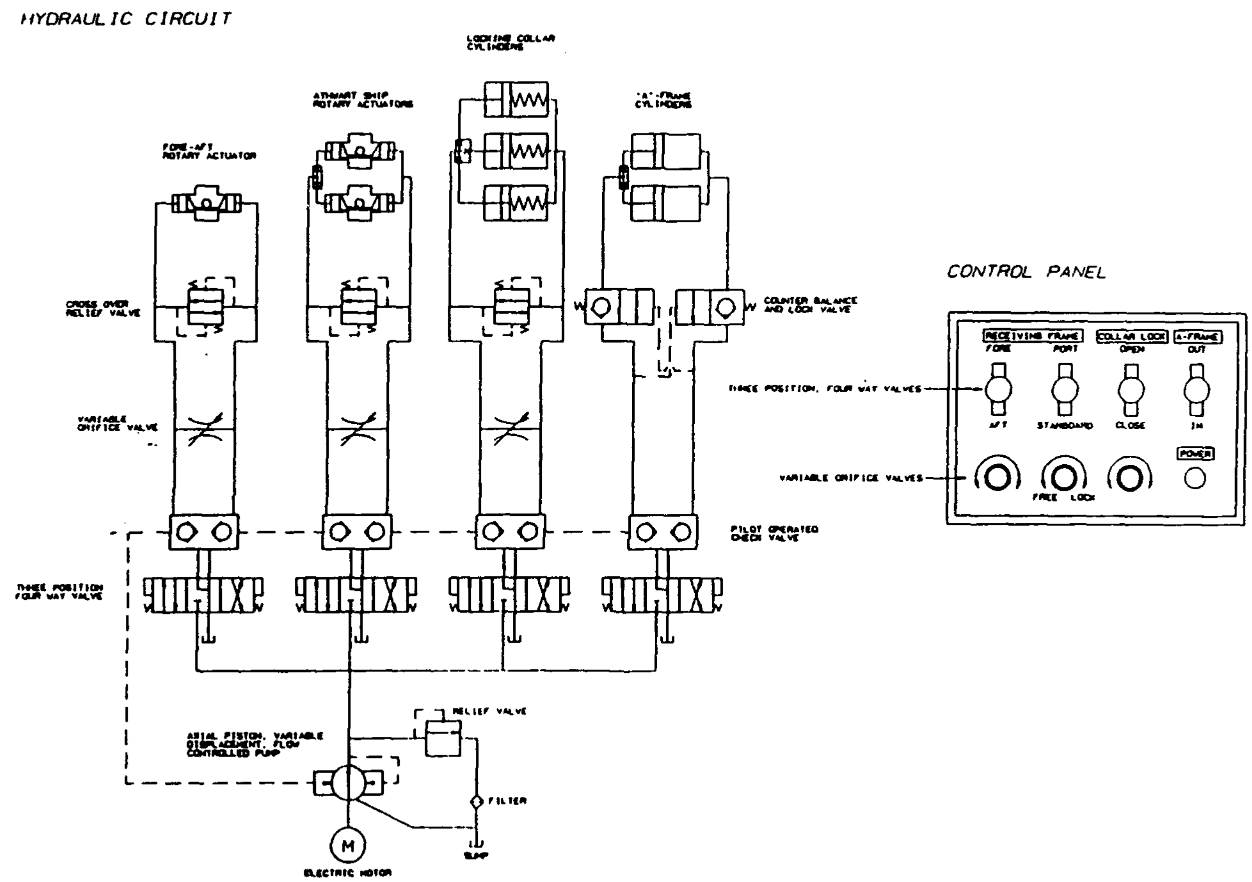


Figure D-3: Hydraulic Control for Launch/Recovery Handling System

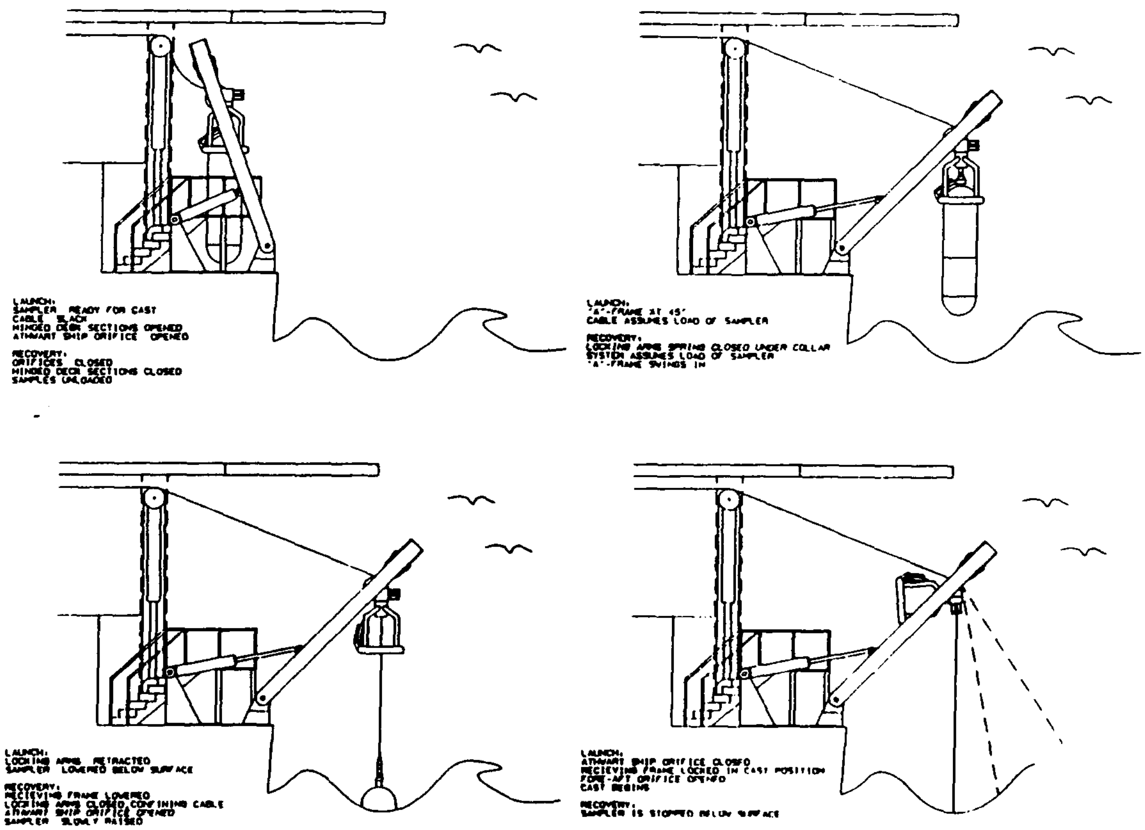


Figure D-4: 4-Step Operation for Launch/Recovery of Underwater Unit

2. The athwartship actuator is partly opened and the fore-aft actuator remains closed. The A-frame travels outboard while the underwater unit remains vertical to prevent contact with the sides of the A-frame.

3. When the A-frame reaches its deployment position, the winch operator takes in the cable slack and transfers the load of the underwater unit from the receiving frame to the winch. The locking mechanism is then opened and the sampler is lowered into the water to a depth of 10 meters.

4. The athwartship actuator is then closed and the receiving frame is raised to the up position. The fore-aft actuator is finally opened, which allows the outboard sheave to follow the cable angle, and the cast begins.

Recovering the unit would begin as it is automatically stopped at a depth of 10 meters below the surface and the motion compensation is deactivated. Recovery is thereafter controlled by the human operator. The receiving frame is next lowered to the vertical position. The locking mechanism is closed, trapping the cable within the locking collar. The athwartship actuator is then opened. The winch operator slowly brings the underwater unit into the receiving frame. When the mushroom section of the underwater unit reaches the locking collar it spreads the mechanism apart. Under the action of springs, the arms snap back down on the collar of the underwater unit. The winch is then stopped and the operator provides a small amount of slack to the cables. The adjustable orifices of the actuators are then gradually closed to damp out the pendulum motion. The A-frame is then brought back to the stowage position. When the stowage position is reached, the orifices are closed and the deck panels of the stowage platform are closed and the handrail is secured.

Motion Compensator

The purpose of the motion compensator is to decouple the water sampler from the wave-induced, violent motion of the head chieve. This will then:

- Allow safe profiling operations in greater sea states than is operationally practical without motion compensation.

- Reduce the dynamic loading of the mechanical components of the system.

- Improve the quality of the CTD profile data by reducing the vertical oscillations of the underwater unit, and thus ensuring good flow past the CTD sensors and a nearly monotonic pressure series.

- Allow better control of the depth at which water samples are collected by effectively reducing the vertical excursions of the underwater unit.

The motion compensator works by keeping the tension in the cable nearly constant, as the ship is heaved by wave motion. As the ship moves v, the motion compensator (not the winch) pays out additional cable to maintain constant tension in the cable. As the ship rolls back down, the motions compensator reacts by taking in extra cable. This can be actively or passively.

The passive motion compensator system (Fig. D-5) uses a hydraulic cylinder connected to an air-fluid (water-based) accumulator and air tanks to passively maintain cable tension. Cable is stored around two sets of sheaves, one set of which is mounted on the moving end of the hydraulic cylinder. As the tension in the cable increases, the cylinder is compressed and stored cabled is payed out by the motion compensator. Similarly, as the cable tension decreases, the cylinder extends and cable is taken up by the motion compensator.

The spring rate and preload of the motion compensator is determined by the air pressure and volume in the air tanks. These characteristics of the motion compensator must be adjusted during the cast, since the load on the cable changes as the underwater unit descends and greater amounts of cable are payed out. Thus, the following changes greatly affect the load that the motion compensator must tolerate:

- Time variations in the effective weight of the underwater unit attached to the lowering cable: the underwater unit weights 1468 lbs empty (prior to entering the water), 3780 lbs when flooded but out of the water (just as it is pulled from the water), and 523 lbs flooded and in the water (including buoyancy of the unit).

- Time variations in the weight of the cable that is in the water.

The principle of operation of the active motion compensation is to electronically sense the pitch, roll and heave motions of the ship and position the wire rope accumulator hydraulic cylinders accordingly to achieve holding the attached package at a fixed location in space. The application of power to position the accumulator hydraulic cylinders greatly reduces the phase lag and system hysteresis caused by mechanical and fluid friction when using the passive type of motion compensator discussed above. The reduction of the effects of phase lag and system hysteresis allows the active motion compensator to be used with line tension load of less than 1,000 lbs. Since the active system is continually keeping track of tension and position, it will automatically adjust for line out and changing instrument weight. Fig D7 shows a diagram of one active compensation system.

While the motion compensator system is a modular package that can be eliminated or deactivated from the system, significant advantages can be gained by its use. Operation of the system without the motion compensator increases the risk of cable snap loads which could break the cable in moderate to high sea states. Furthermore, wave-induced vessel heave can degrade CTD data quality when the underwater unit is momentarily pulled upward during downcast operations.

Fig. D-6 shows the maximum and minimum calculated velocity of underwater unit due to a winch lowering speed of 1.5 m/sec and ship motion at sea state 5 with and without a motion compensator. Negative velocity means that the unit is moving up in the water column. As illustrated in Fig. D-6, the motion compensator offers a significant improvement in the velocity variations. Even at lower sea states, the cable has the potential to overtake the underwater unit after there is a bout 600 meters of cable out. Thus, a motion compensator will significantly improve data quality and safe operational sea state. An important factor in either system is the length of compensation and winch speed. the length of compensation may be difficult to achievce in all sea states desired for profiling operations.

Safety Issues

To ensure safety of personnel and prevent losses of equipment during transit, launch/recovery, and cast operations, a number of safety features have been considered during the conceptual design phase. Issues of particular importance which have been identified include:

- Cable Guard Length. Alarm signals will be activated during recovery, first at 100 meters below the surface to alert personnel that the underwater unit is nearing the surface. At 10 meters below the surface the alarm will be activated again and winch control will be automatically transferred to manual.

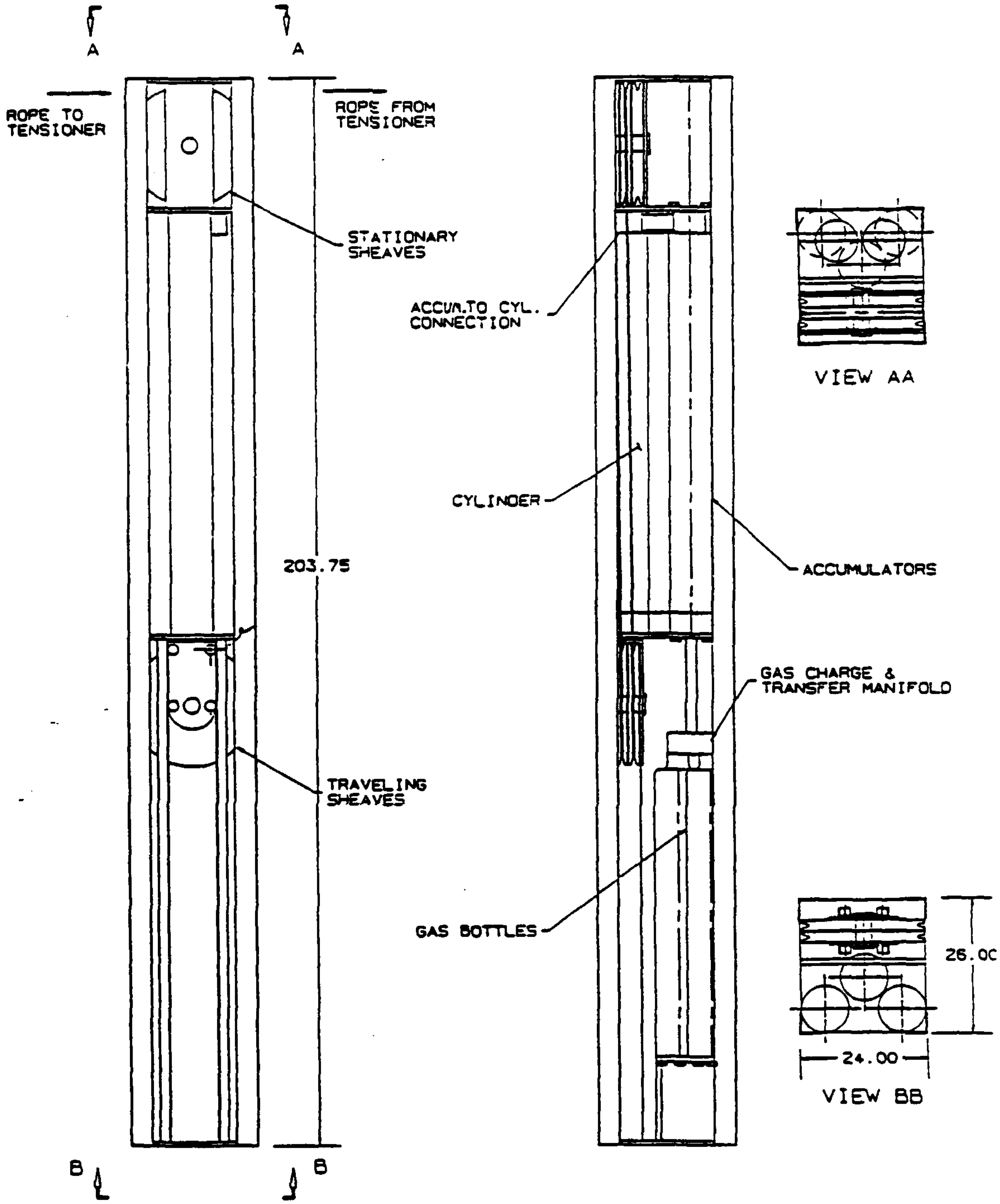


Figure D-5: Motion Compensator Conceptual Design

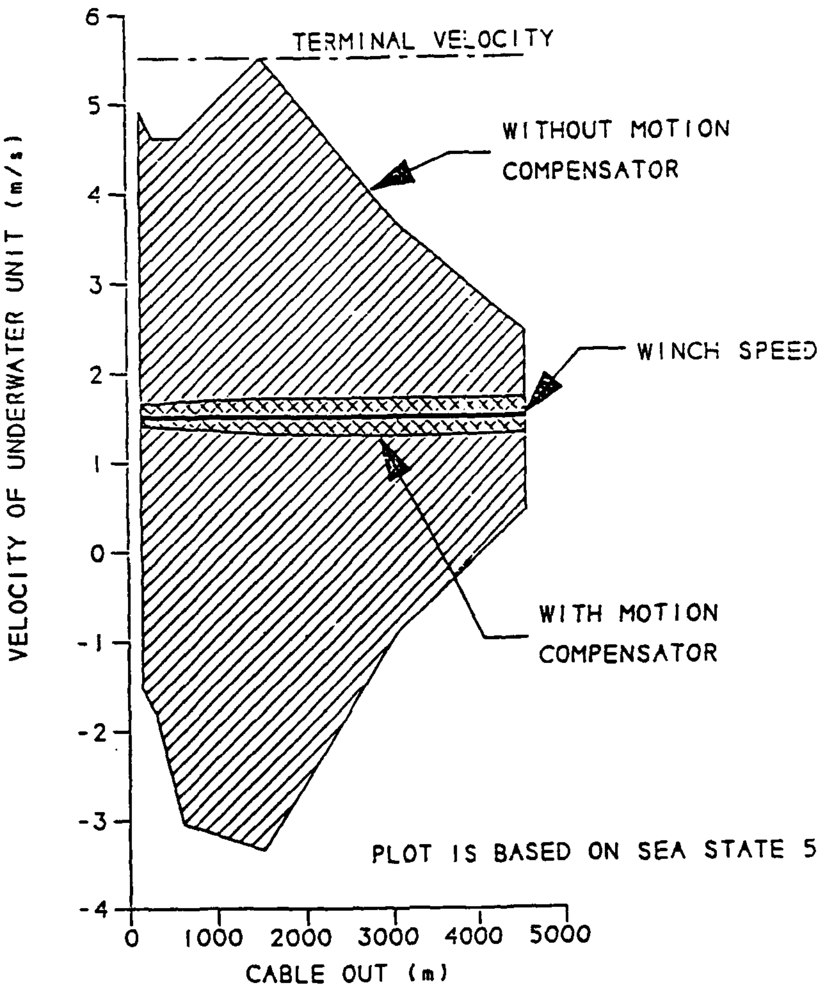


Figure D-6: Velocity With and Without Motion Compensator

- Emergency hauling. In case of breakdown of the launch/recovery system, provisions will be made for taking hold and hauling the underwater unit out of the water by conventional means (points of hold and lift on the sampler).

- Cable breakage. Safety features must be devised to avoid complete loss of the underwater unit at the time of recovery due to cable breakage. Examples of these could be quadruple armoring of the cable over the last 50 or 100 meters, or marrying a strong nylon line to the cable for a small portion of its upper length.

- Relief Valves. Valves will be incorporated into the hydraulic system to prevent the build-up of high pressure and the parting of hoses, cable, or components.

- Control Console. Controls to operate the winch, the A-frame, and the handling system will be located and designed to provide maximum visibility and easy-to-read and understand displays.

- Sample Transfer. The drawers will be designed to be easy to collect and replace. Carrying will be possible using one hand only. The on-deck stowage platform and its access will be designed for maximum protection of personnel using anti-skid grating, rails, and partitions as required.

Deck Handling Control Unit

The principal functions of the Deck Handling Control Unit (DHCU) are to:

- Provide the control computer with status information from the motion compensator and the winch.

- Execute actuator control of the winch during an auto-cast.

- Execute actuator control of the motion compensator based on cable-out information.

- Ensure operation safety during automatic control periods.

- Provide for quick disabling of control functions if malfunction or upon operator request.

The DHCU is a passive device in that it only provides an interface from the winch and motion compensator to the control computer. The control computer makes all control decisions. The DHCU will collect and communicate data on the motion of the compensator system to the control computer. The control computer feeds back actuator data to the DHCU to perform the control functions.

Fig. D-8 presents a block diagram for the DHCU. The unit is based upon the 80C54-Basic micro-controller card. The sensors for the DHCU system consist of a cable speed and meter out sensor, a ram tensioner pressure sensor, and an acoustic ram position sensor. Tracking ram position will sense if the mean position is moving to one end of travel. If the mean position moves too far, the pressure will be adjusted to return the mean to the center of travel. The unit also interfaces to the winch motor controller to control the speed of the winch.

Active control of the motion compensator's accumulator will be via three control switches which select accumulator spring rates and pressure. To evaluate motion compensator performance during the sea tests, the system will be equipped with 2-axis tilt and 2-axis accelerometers from which the roll and heave motion of the ship will be determined. The relationship between underwater unit motion and ship's motion will be correlated to determine the effect of changes on the compensator control algorithm during Phase II. The ship motion will not be

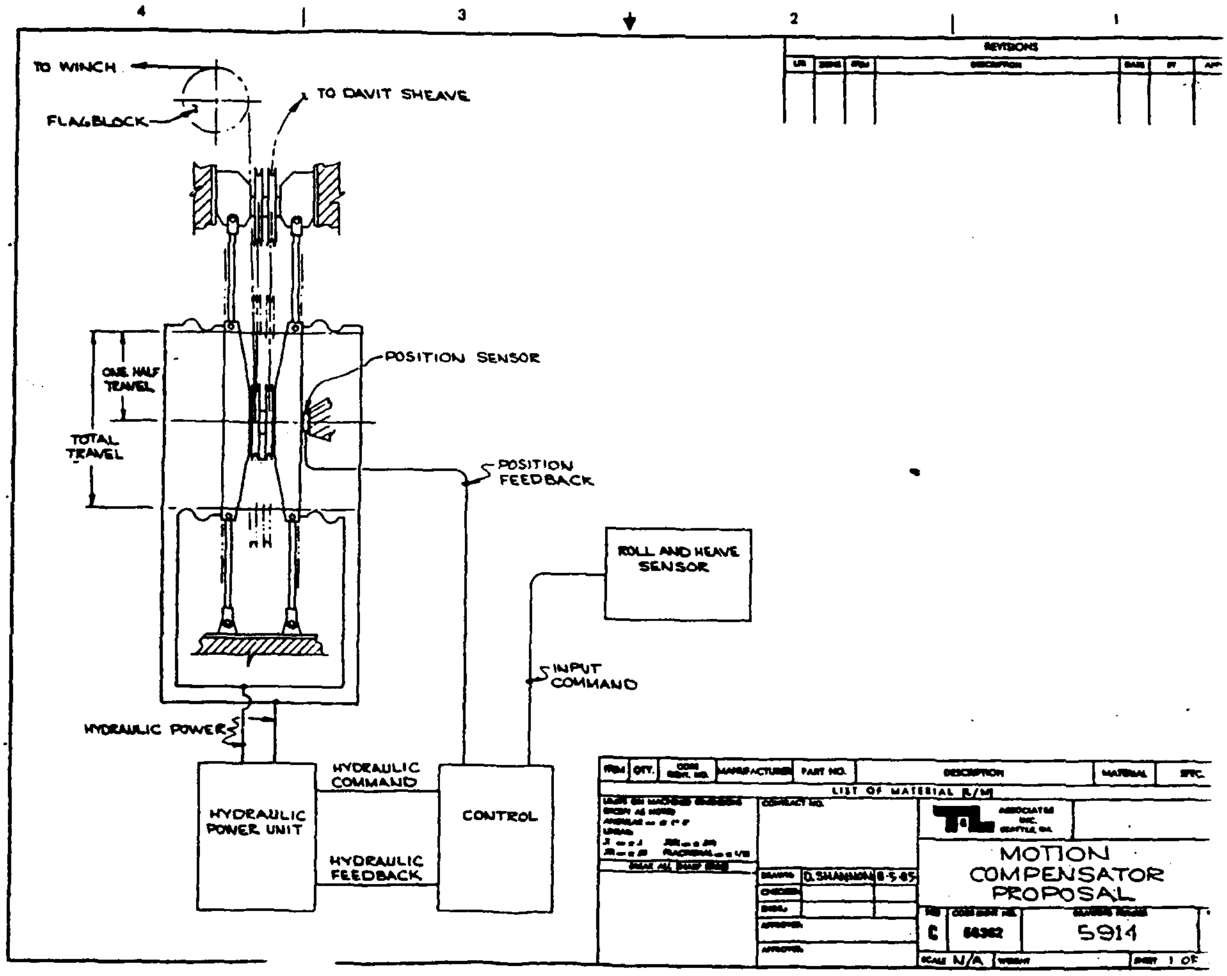


Figure D-7: Motion Compensator Block Diagram

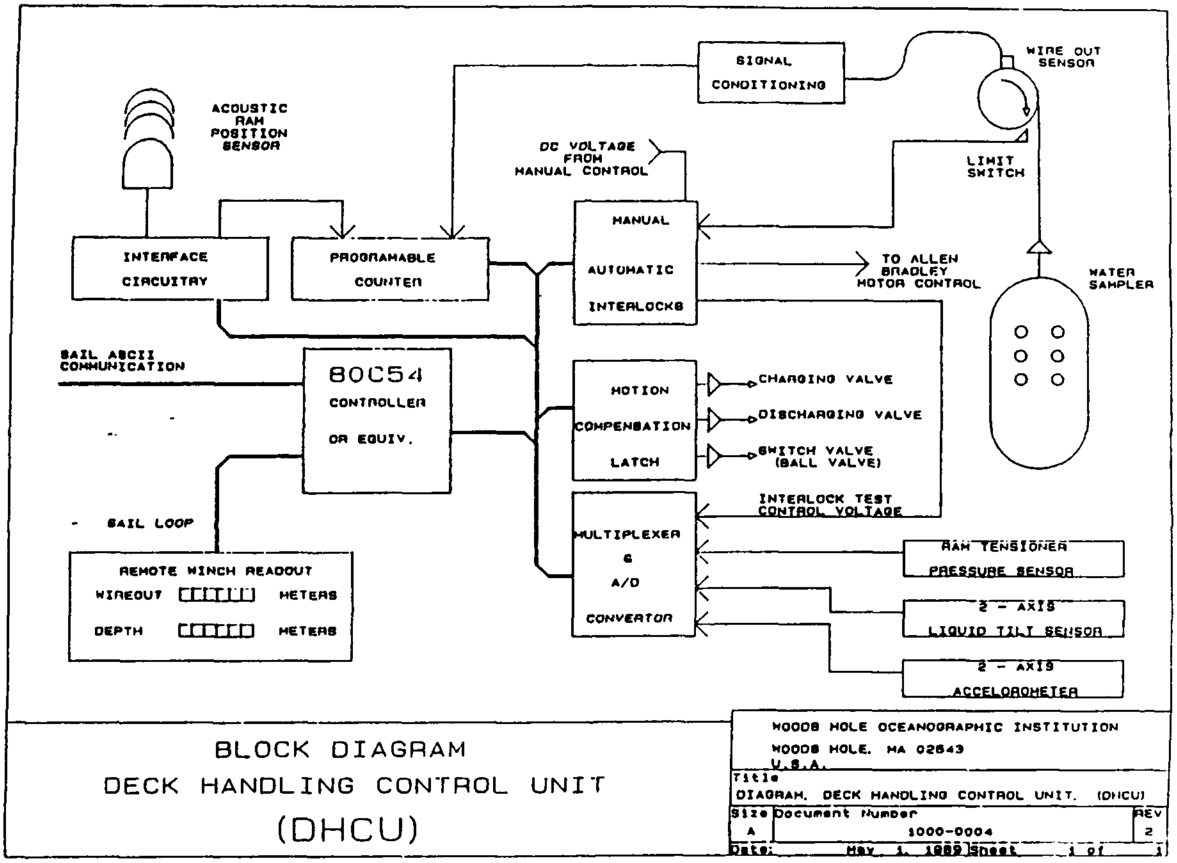


Figure D-8: Deck Handling Control Unit

required on production systems, as they are not used for actual control of the compensator.

The prototype DHCU will control the winch on the R/V OCEANUS which is typical on several UNOLS vessels. This winch is a Markey-type DESH-5 research winch driven by a 60 hp DC motor. The motor is controlled by an Allen-Bradley armature regenerative motor controller. The manual control handle operates a wiper on ta potentiometer that generates a DC voltage signal (± 8 volts) to the Allen-Bradley winch controller. The DHCU will provide this voltage as an output from an 8-bit digital to analog converter. Based on commands from the control computer, the DHCU will change the output voltage to control winch direction and rate. The cable rate is proportional to the applied voltage.

To control acceleration and deceleration, the Allen-Bradley winch controller has hardwired time constants from 0.1 seconds to 15 seconds. The control computer will accomplish the same results by programming a low pass filter response in the data given as output to the winch controller. The jumper setting of the Allen-Bradley controller will be set to its shortest interval of 0.1 seconds.

The DHCU will provide a continuous display of lowering rate and total cable-out to the winch operator. The display will consist of a large, waterproof LED readout.

Winch Control Interlock

For operational safety, the DHCU has a winch control interlock. Fig. D-9 presents a block diagram of the winch control interlock. The principal objectives of the interlock are:

- Provide the winch operator with a manual override of the automatic system.
- for existing operation of the winch.
- Provide a warning to the operator when the winch enters automatic control.

The interlock system allows for immediate manual override of the automatic controller. Two manual switches are used to engage the controller. When the controller is engaged, the operator is warned both visually and audibly. The DHCU will monitor the output of this D/A converter to insure that it is at zero volts, prior to allowing the system to enter the automatic control mode. Sealed reed relays are used to switch the signal path to the controller. A series interlock system is designed to disengage the automatic controller if the system or operator detect a problem. A indicated in Fig. D-9, SW1 is normally on contact 2 and pulled to contact 1 when energized. Switches SW3 and SW5 must be manually pulled on to allow the controller to actuate the winch by turning on transistor switch Q1. An LED in series with the transistor switch Q1 is lit and an alarm sounds three times when the system enters the automatic mode.

Another safety feature built into the DHCU is a limit switch in the receiving frame on the Launch/Recovery handling system. When the underwater unit contacts this switch, the DHCU will stop the winch to prevent two-blocking which could result in failure of the cable.

Control Software

A customized, user-friendly software package will be required for control of the integrated seawater sampler and data acquisition system. The general approach will be to develop a library of software control modules that control the individual hardware components of the system (e.g., the winch and the motion compensator). Software will also be developed for acquisition and display of the CTD data, but we expect that each user (principal investigator) will want to

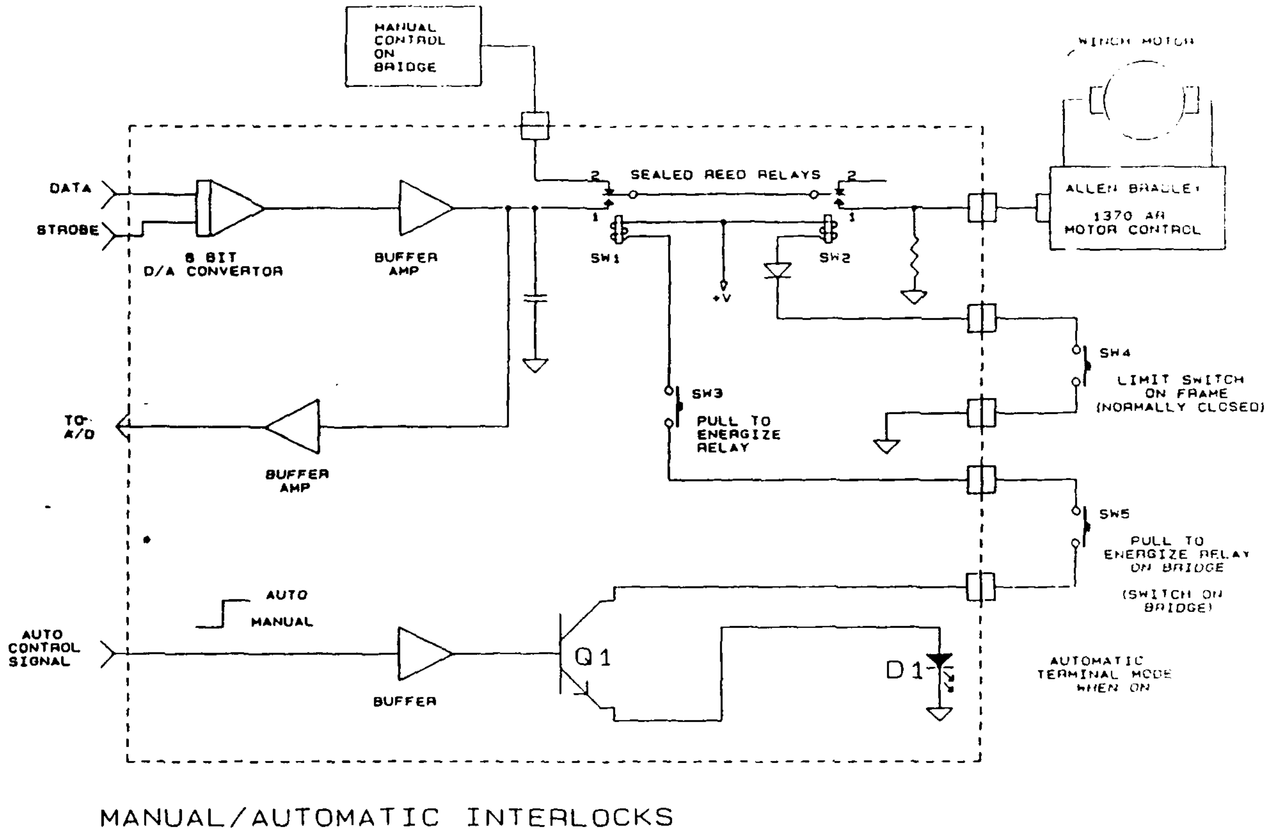


Figure D-9: Winch Control Interlock Block Diagram

integrate his/her own CTD acquisition/processing software with the modules for control of the entire system.

The control software wil have five primary functions:

- Control of the water sampler
- Acquisition and display of CTD data
- Acquisition and display of data from the bottom-finding altimeter
- Optional control of the winch during the cast
- Control of the motion compensator

Based on the information in the cast file, the control software will command the water sample control unit to take a water sample when at the desired depth; the sample volume wiall also be specified. When the underwater unit starts its ascent, the software will command that the exhaust valve be adjusted for discharging pump water downward in the wake of the underwater unit. To control the winch, the software will give the DHCU a speed setting based on percent of maximum speed o fthe winch. The DHCU will do the actual adjusting of the winch speed setting. Based on wireout and RAM position information, the software will tell the DHCU how long to open the charging or bleeding valves to adjust the motion compensator accumulator pressure.

During Phase I, the command and status protocols were developed for the communication between the control computer and the other system components. These protocols were developed in parallel with the basic functions that will be executed during each cast. During the cast, the software package will be collecting CTD data and monitoring the following information from the underwater unit, the winch, the motion compensator, and the bottom-finding altimeter:

- Position of the rotary valve
- Number and volume of last sample taken
- Exhaust valve position
- Underwater unit battery voltage
- Winch speed and direction
- Wireout
- Motion compensator accumulator pressure
- Motion compensator ram piston position
- Depth of underwater unit
- Height above the bottom

The control software package will be written in Microsoft QuickBasic on an IBM-compatible computer. The program will be written in modular form consixsting of the main menu and seven major modules with supporting input, output, and graphic driver modules. The seven major modules are:

- Cast Plan Screen - A spreadsheet type module for entering station information prior to profiling operatings usch as water depth, volume and depth of individual water sampling on downcast or upcast.

- Real-Time Cast Screen - A module that drives the screen display showing such information as vertical profiles of CTD data, water sample data (volumes, depths, empty/full), cable out, winch and underwatert unit speed, and distance off bottom.

- Water Sampler Control - A module for controlling the water sampler and getting status information from wataer sampler.

- CTD Control - A mudule for interfacing with CTD, achieving the binary data, and converting the binary data into oceanographic units. One module will be developed for eadh of the two CTDs (Sea-Bird and EG&G).

- Winch Control - A module for controlling the winch such as setting winch speed, keeping track of wire out, and slowing down and stopping winch when the underwater unit gets near the ocean bottom and upon nearing the surface during upcast.

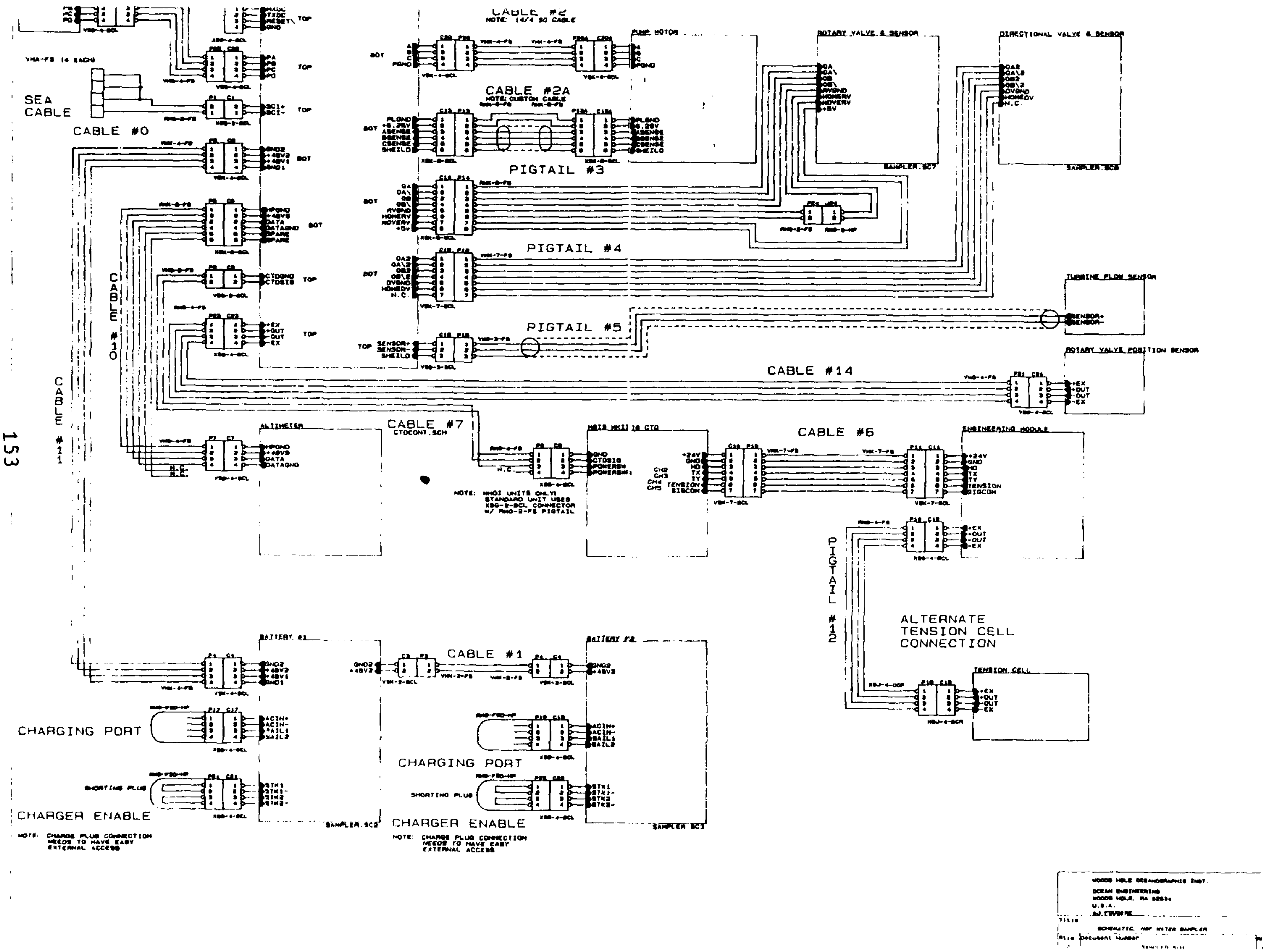
- Motion Compensator Control - A module for controlling the motion compensator such as adjusting accumulator presssure based on wire out or when the ram piston sensor indicates that the piston is getting too close to one end of its stroke range.

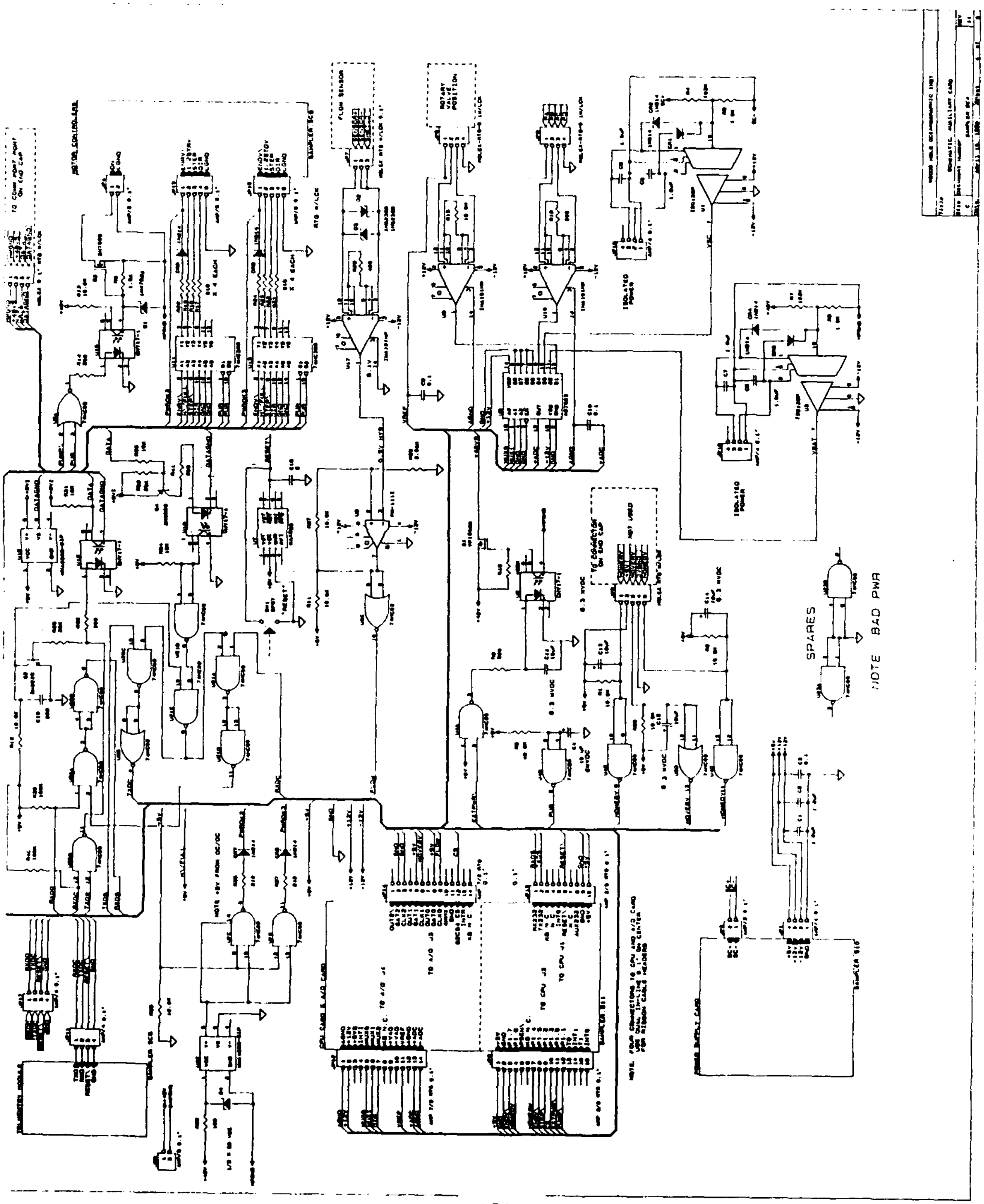
- Hardcopy - A module for printing hardcopies of information in printed and graphical forms.

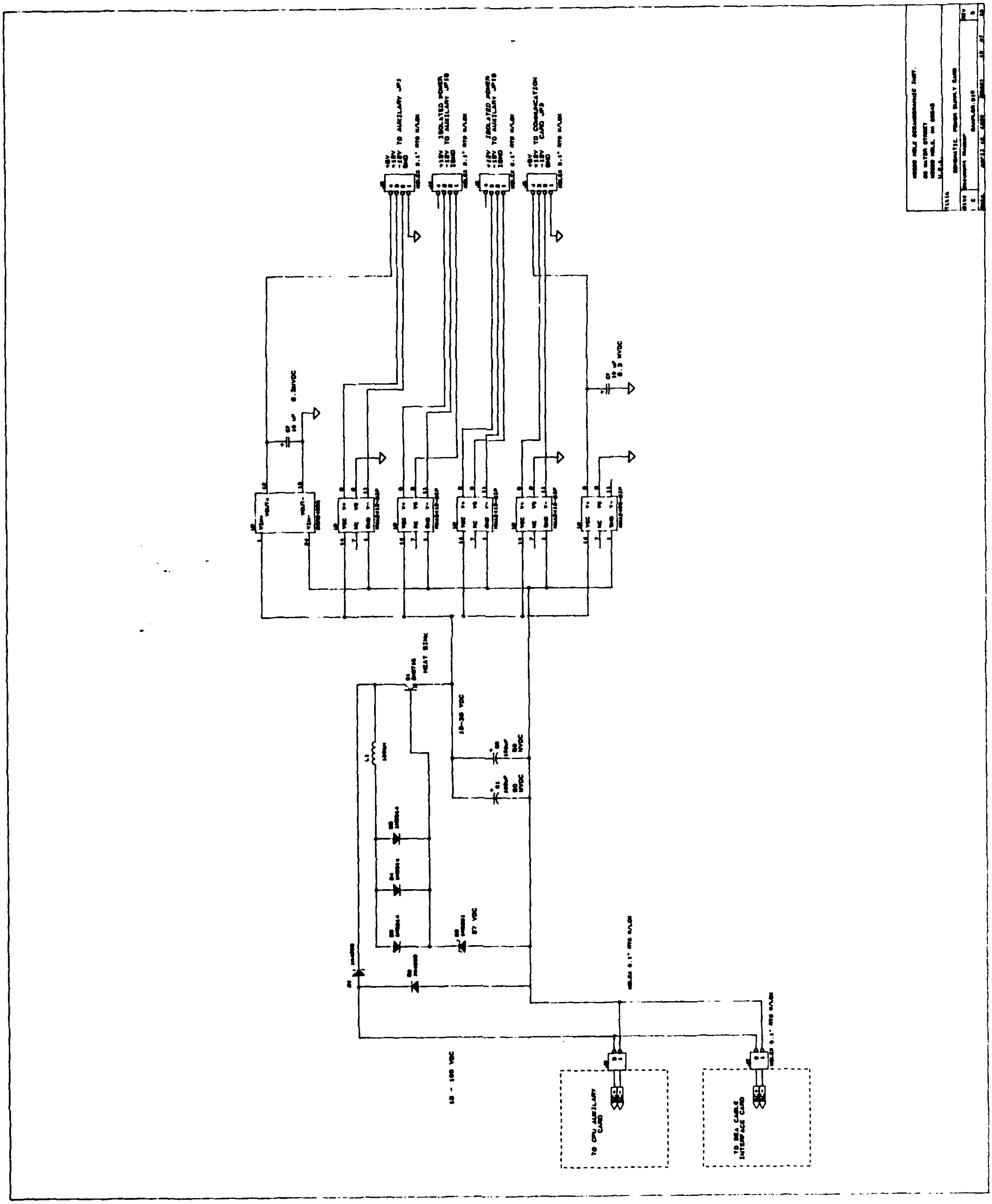
DOCUMENTATION

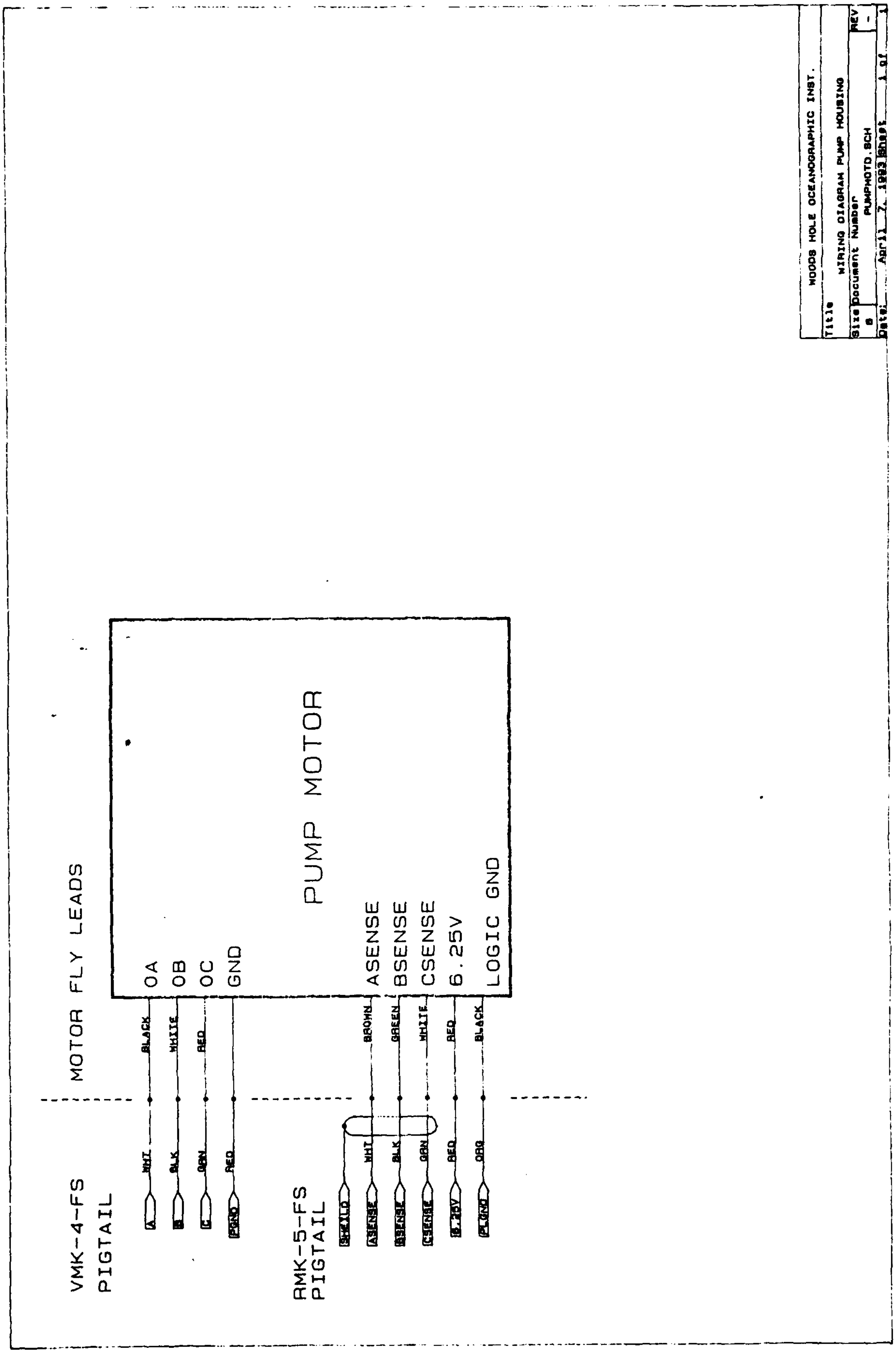
A: Electronic Schematics (WHOI)

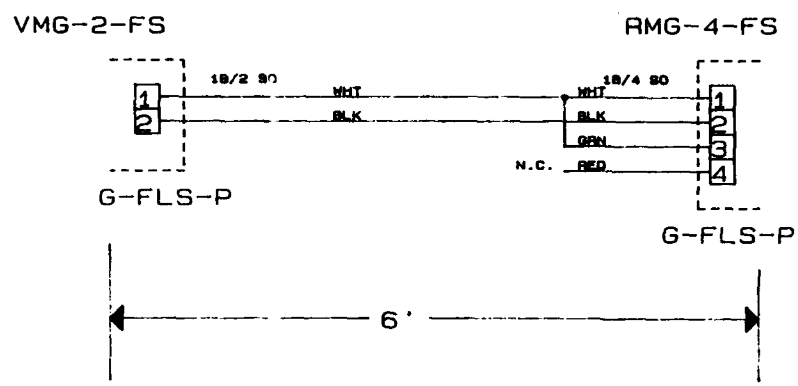
Water Sampler System Schematic	SAMPLER.SCH
Auxilliary Card Schematic	SAMPLER.SC4
Power Supply Card	SAMPLER.S10
Wiring Diagram of Pump Housing	PUMPMOTD.SCH
Wiring Diagram - CTD to Controller Cable	CTDCONT.SCH
Wiring Diagram - Sea Cable to Controller	TERMCONT.SCH
Sampler Chassis Wiring for Motor Controllers	SAMPLER.SC9
Interconnections - CPU Card to A/D Card	SAMPLER.S11
Battery Pack # 1 Schematic	BAT1TEMP.SCH
Battery Pack # 2 Schematic	BAT2TEMP.SCH
Wiring for Directional Valve Housing	SAMPLER.SC8
Wiring Diagram - Pigtail #3, Rotary Valve	RVCABLE.SCH
Rotary Valve Housing Schematic	SAMPLER.SC7
Sampler Modem Schematic	SAMPLER.SC6
Sea Cable Coupling Card Schematic	SAMPLER.S17
Engineering Module Schematic	ENGMOD.SCH
Sampler Deck Modem Schematic	SAMPDU.SCH
Sampler Deck Modem Power Supply Schematic	SAMPDU3.SCH
Sampler Telemetry Schematic	SAMPLER.SC5


CABLE #0
SEA CABLE
CABLE #1
CABLE #2
CABLE #2A
CABLE #6
CABLE #7
CABLE #10
CABLE #11
CABLE #14
PIGTAIL #3
PIGTAIL #4
PIGTAIL #5
PIGTAIL #12
ALTERNATE TENSION CELL CONNECTION
CHARGING PORT
CHARGER ENABLE
CHARGING PORT
CHARGER ENABLE



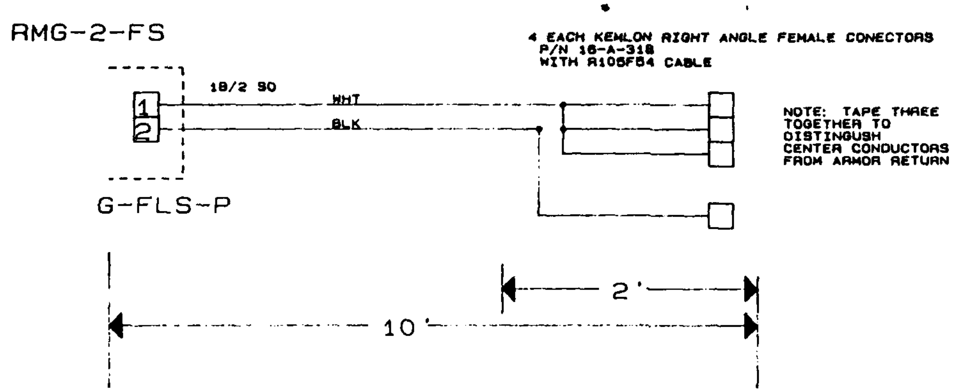

TO CPU AUXILIARY CARD
TO SEA CABLE INTERFACE CARD
18 - 100 VDC
HEAT SINK
27 VDC
ISOLATED POWER
TO COMMUNICATION CARD JP3


WOODS HOLE OCEANOGRAPHIC INST.
Title
WIRING DIAGRAM PUMP HOUSING
Size B
Document Number
PUMPMOTD.SCH
REV -
Date: April 7, 1993
Sheet 1 of 1
MOTOR FLY LEADS
PUMP MOTOR
OA
OB
OC
GND
ASENSE
BSENSE
CSENSE
6.25V
LOGIC GND
BLACK
WHITE
RED
BROWN
GREEN
WHITE
RED
BLACK
WHT
BLK
GRN
RED
WHT
BLK
GRN
RED
ORG
A
B
C
PGND
SHEILD
ASENSE
BSENSE
CSENSE
6.25V
PLGND
VMK-4-FS
PIGTAIL
RMK-5-FS
PIGTAIL



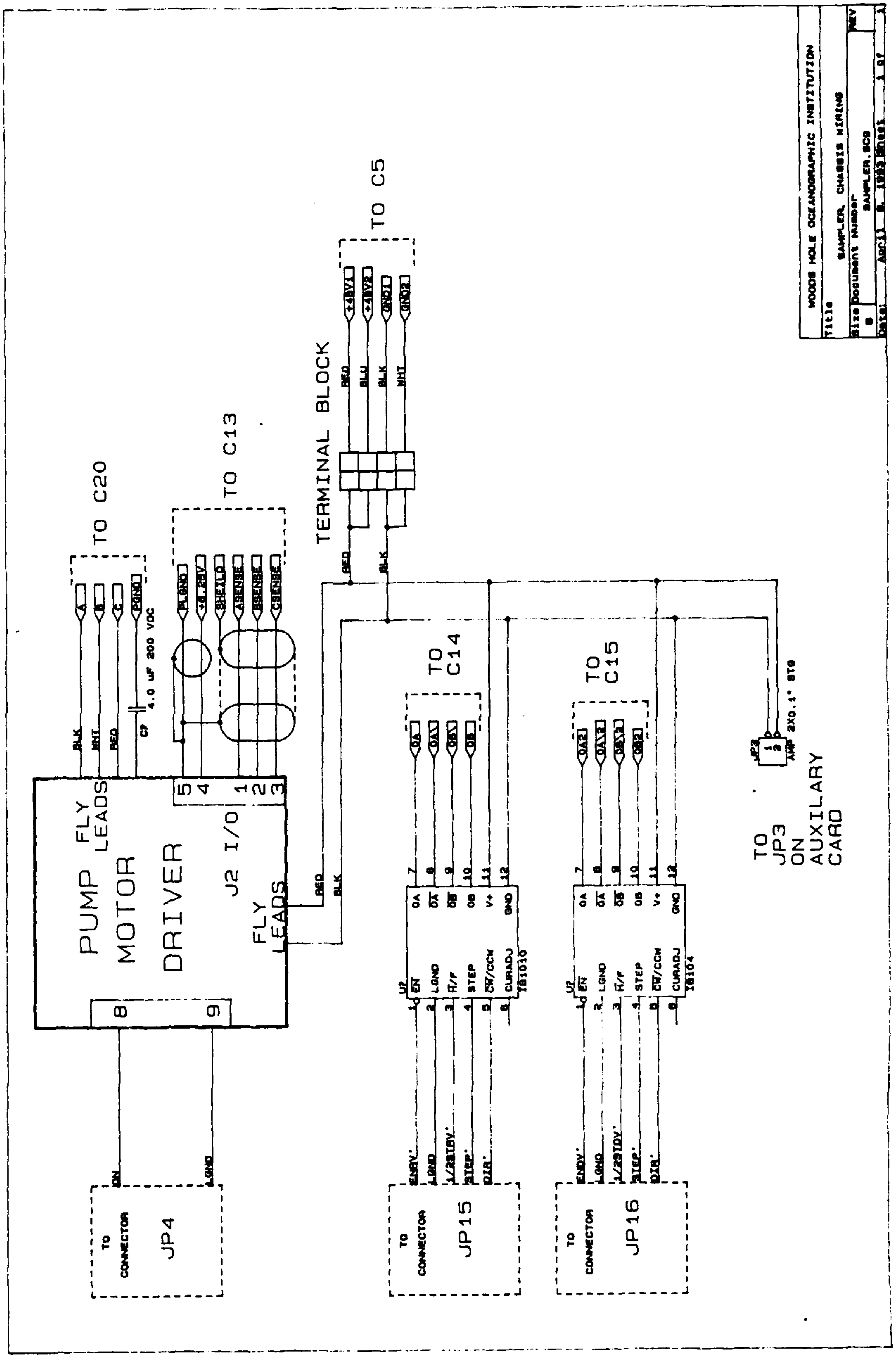
NOTE: PRESSURE TEST TO 10,000 PSIA

WOODS HOLE OCEANOGRAPHIC INST.		
Title: CABLE, CTD TO CONTROLLER		
Size: B	Document Number: CTDCONT.SCH	REV: 1
Date: April 8, 1993	Sheet 1 of 1	

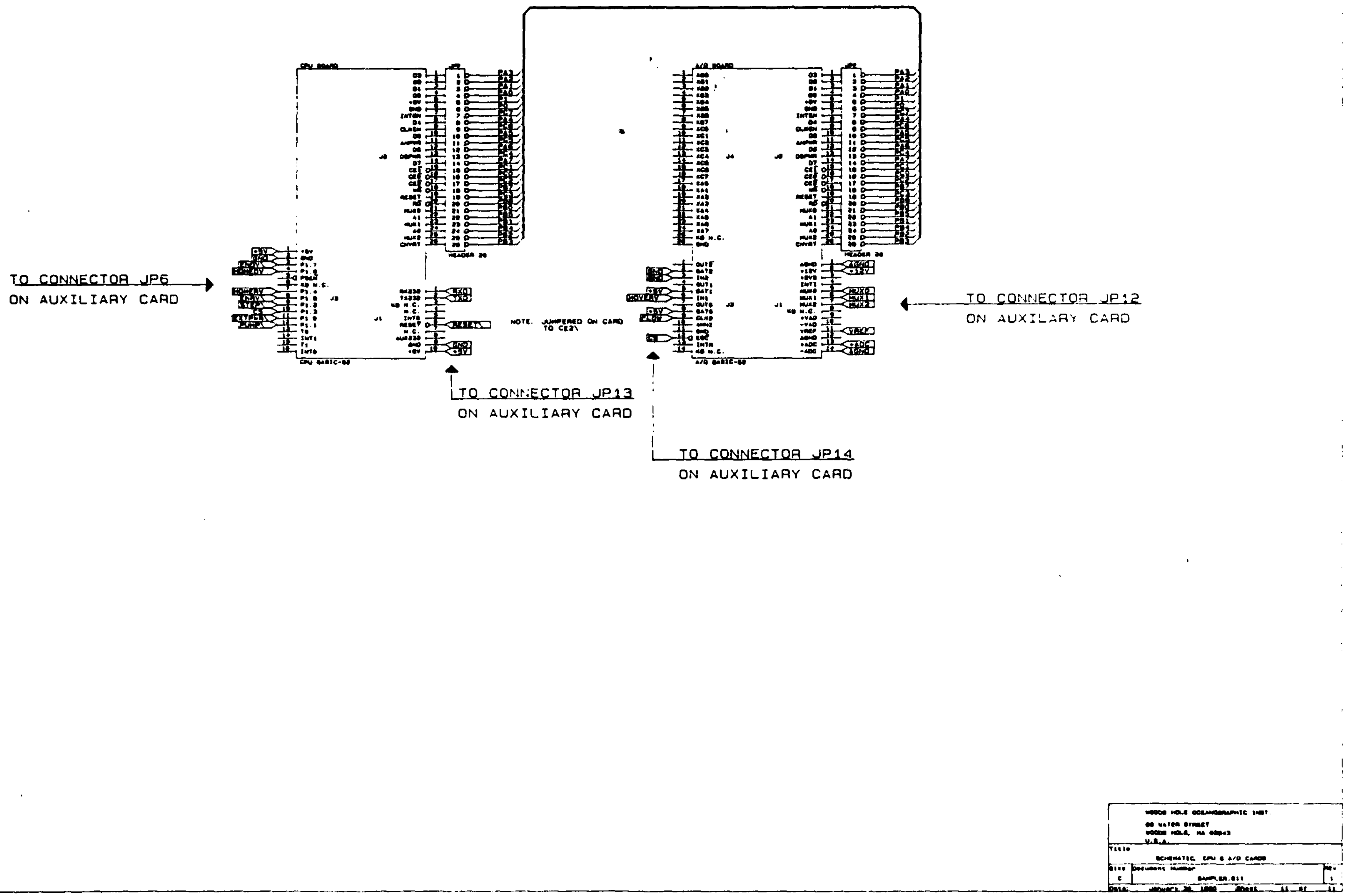


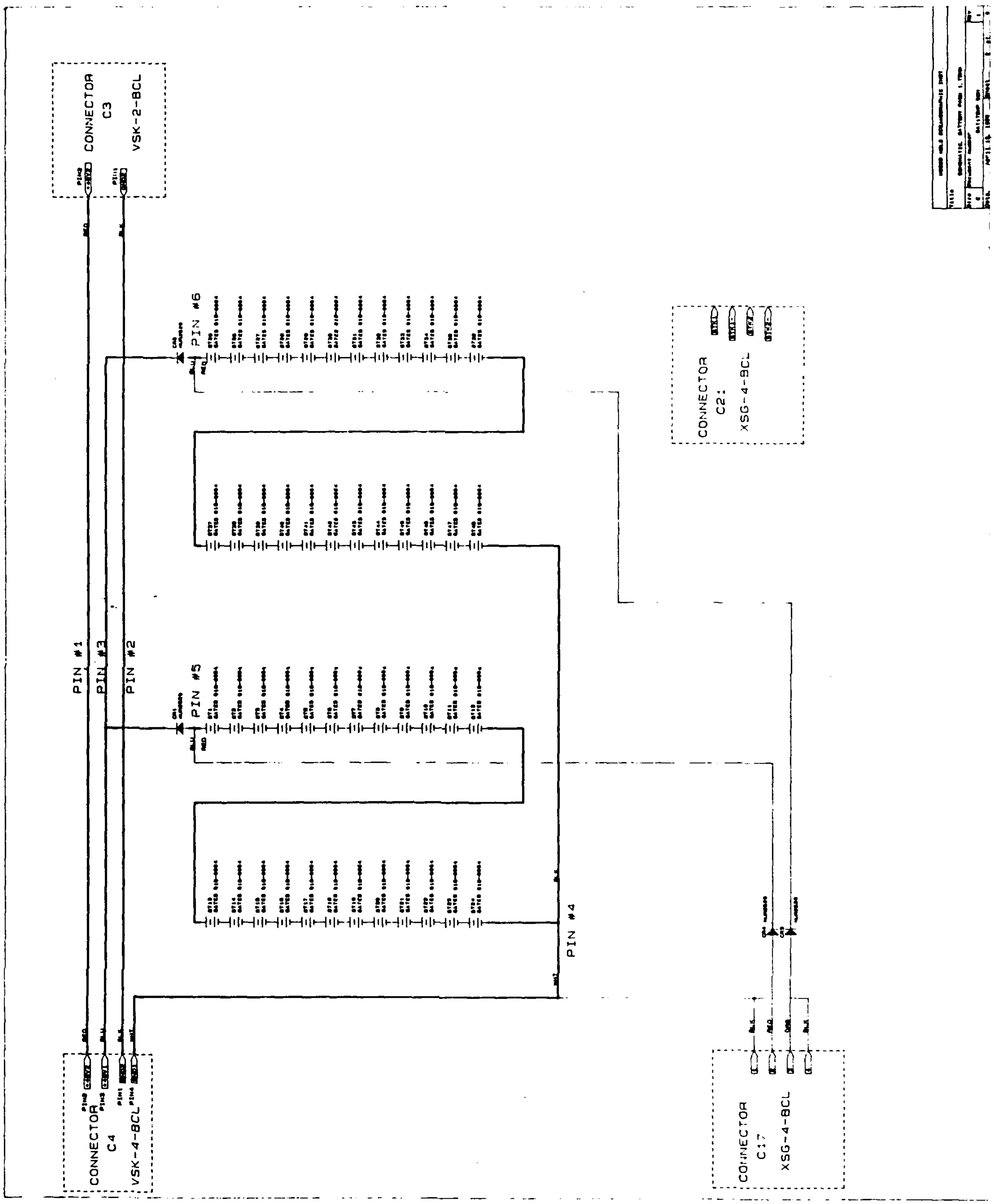
NOTE: PRESSURE TEST TO 10,000 PSIA

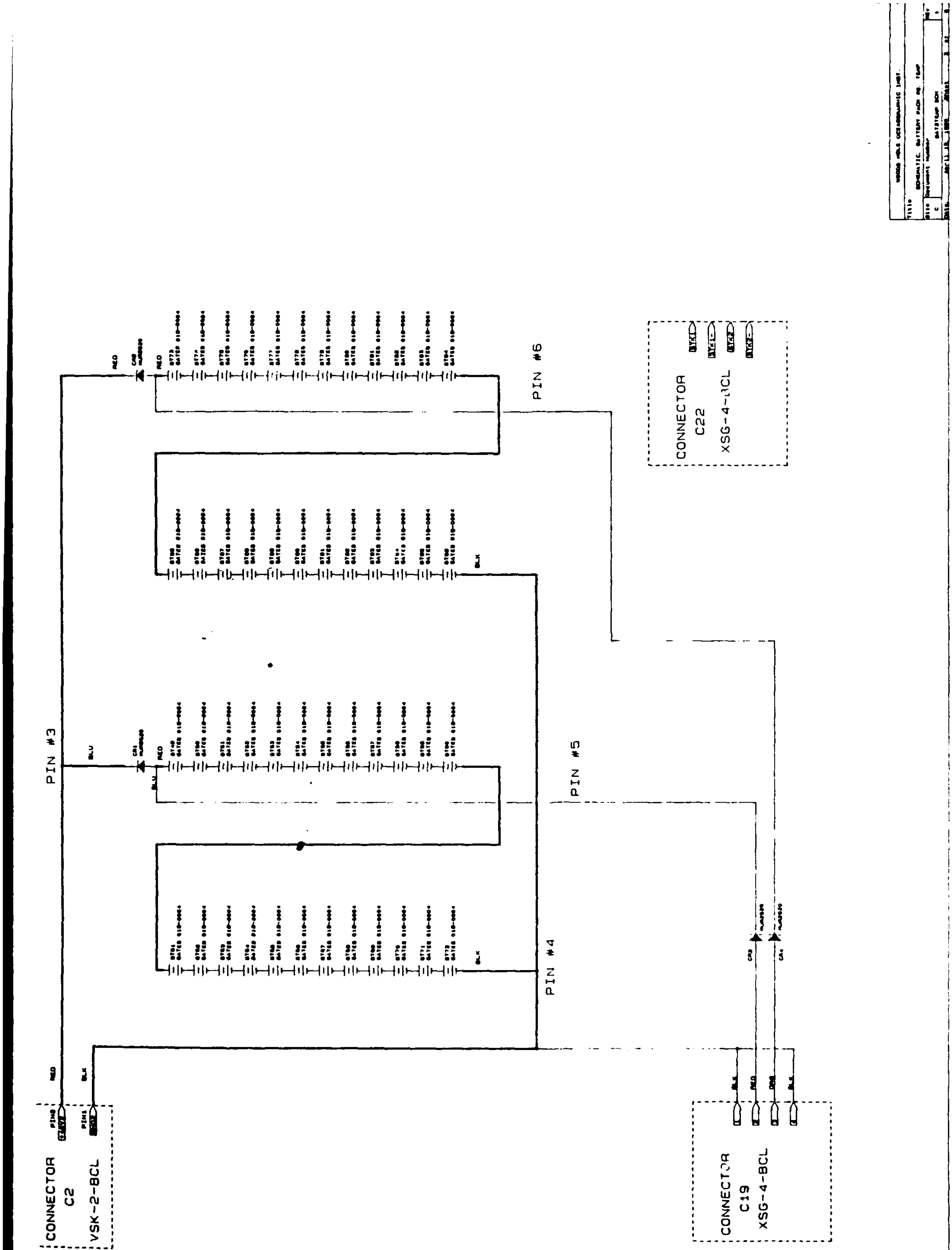
WOODS HOLE OCEANOGRAPHIC INST.			
Title CABLE, TERMINATION TO CONTROLLER			
Size B	Document Number TERMCONT.SCH		REV -
Date: April 8, 1993	Sheet 1 of 1		

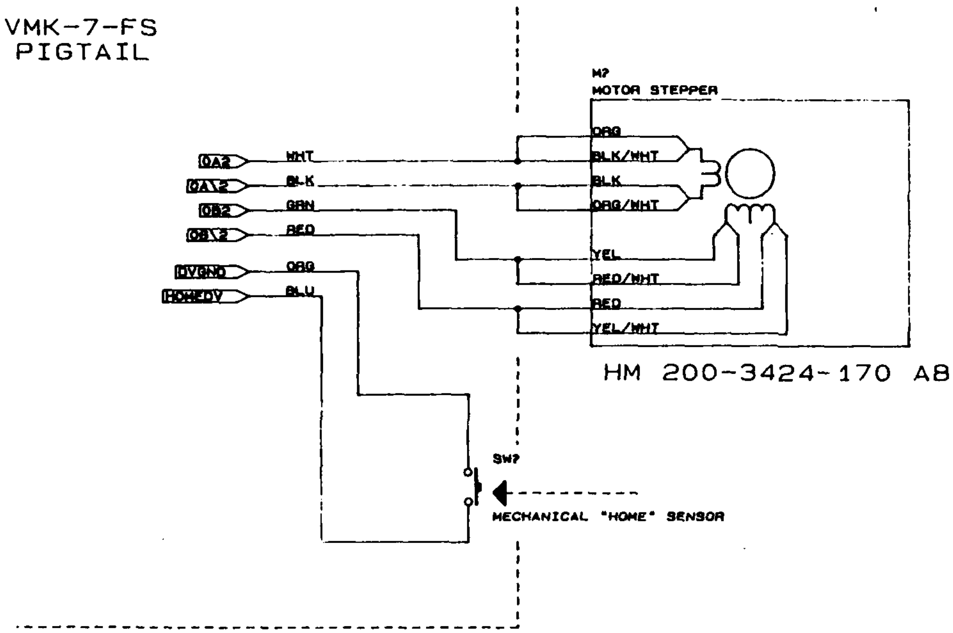


WOODS HOLE OCEANOGRAPHIC INSTITUTION
Title SAMPLER, CHASSIS WIRING
Size B Document Number SAMPLER.SCG REV 1
Date: April 8, 1993 Sheet 1 of 1
TO C5
TERMINAL BLOCK
TO C13
TO C20
PUMP MOTOR DRIVER
FLY LEADS
J2 I/O
TO C14
TO C15
TO JP3 ON AUXILARY CARD
AMP 2X0.1" STG
C7 4.0 uF 200 VDC
TO CONNECTOR JP4
TO CONNECTOR JP15
TO CONNECTOR JP16


TO CONNECTOR JP6
ON AUXILIARY CARD
TO CONNECTOR JP13
ON AUXILIARY CARD
NOTE. JUMPERED ON CARD TO CE2\
TO CONNECTOR JP14
ON AUXILIARY CARD
TO CONNECTOR JP12
ON AUXILARY CARD

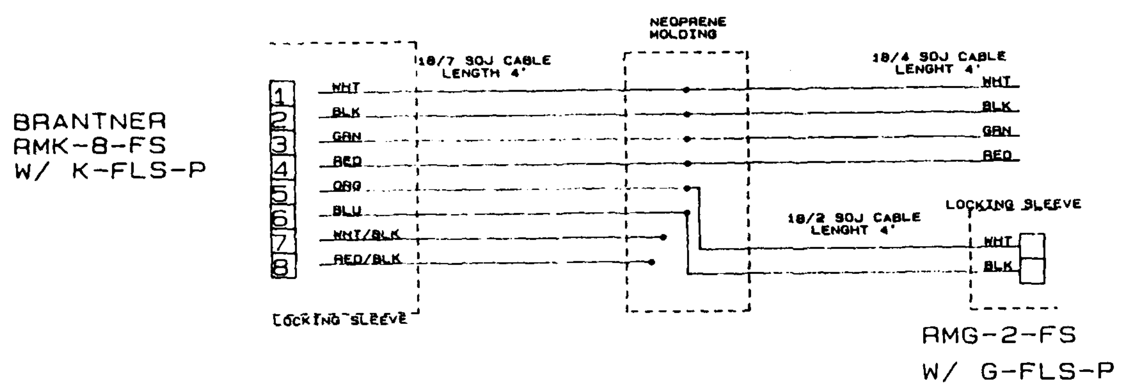

CONNECTOR
C3
VSK-2-BCL
PIN #6
CONNECTOR
C21
XSG-4-BCL
PIN #1
PIN #3
PIN #2
PIN #5
PIN #4
CONNECTOR
C4
VSK-4-BCL
CONNECTOR
C17
XSG-4-BCL


PIN #3
PIN #4
PIN #5
PIN #6
CONNECTOR C2 VSK-2-BCL
CONNECTOR C19 XSG-4-BCL
CONNECTOR C22 XSG-4-BCL

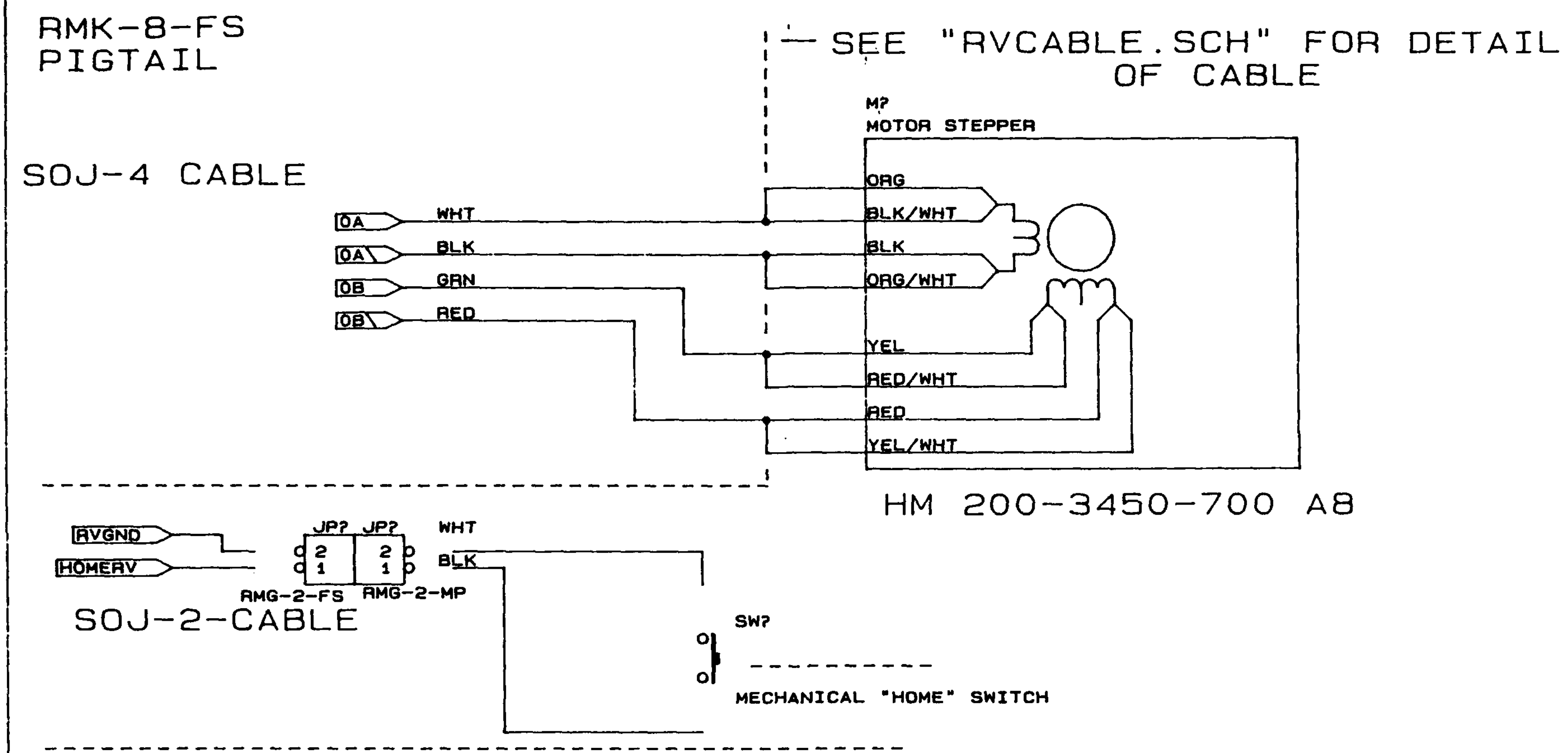


WOOD HOLE OCEANOGRAPHIC INST.		
Title: SCHEMATIC, DIRECTIONAL VALVE HOUSING		
Size: B	Document Number: SAMPLER.SCH	REV: -
Date: April 8, 1993	Sheet 8 of 8	

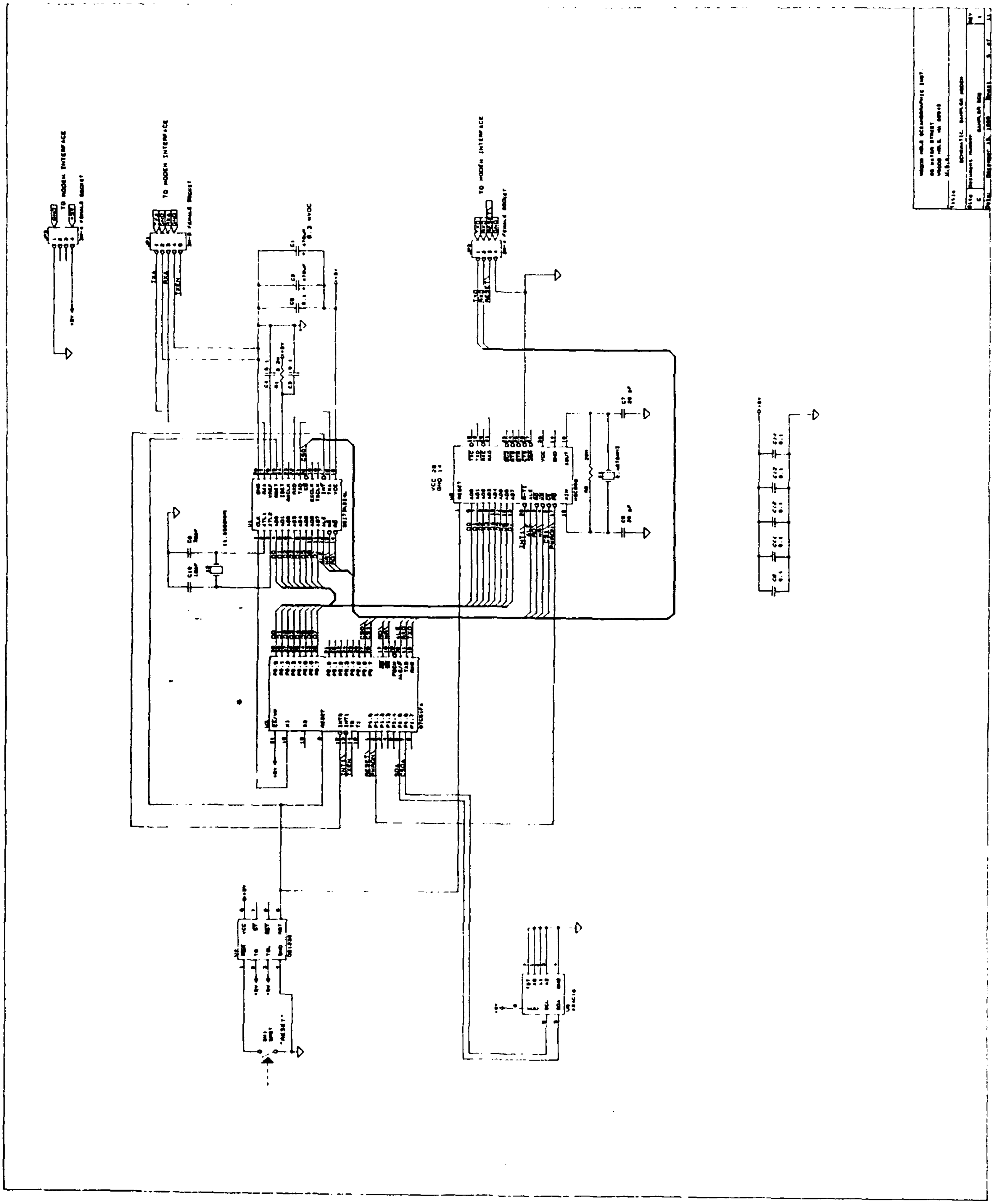
PRESSURE TEST TO 10,000 PSIA

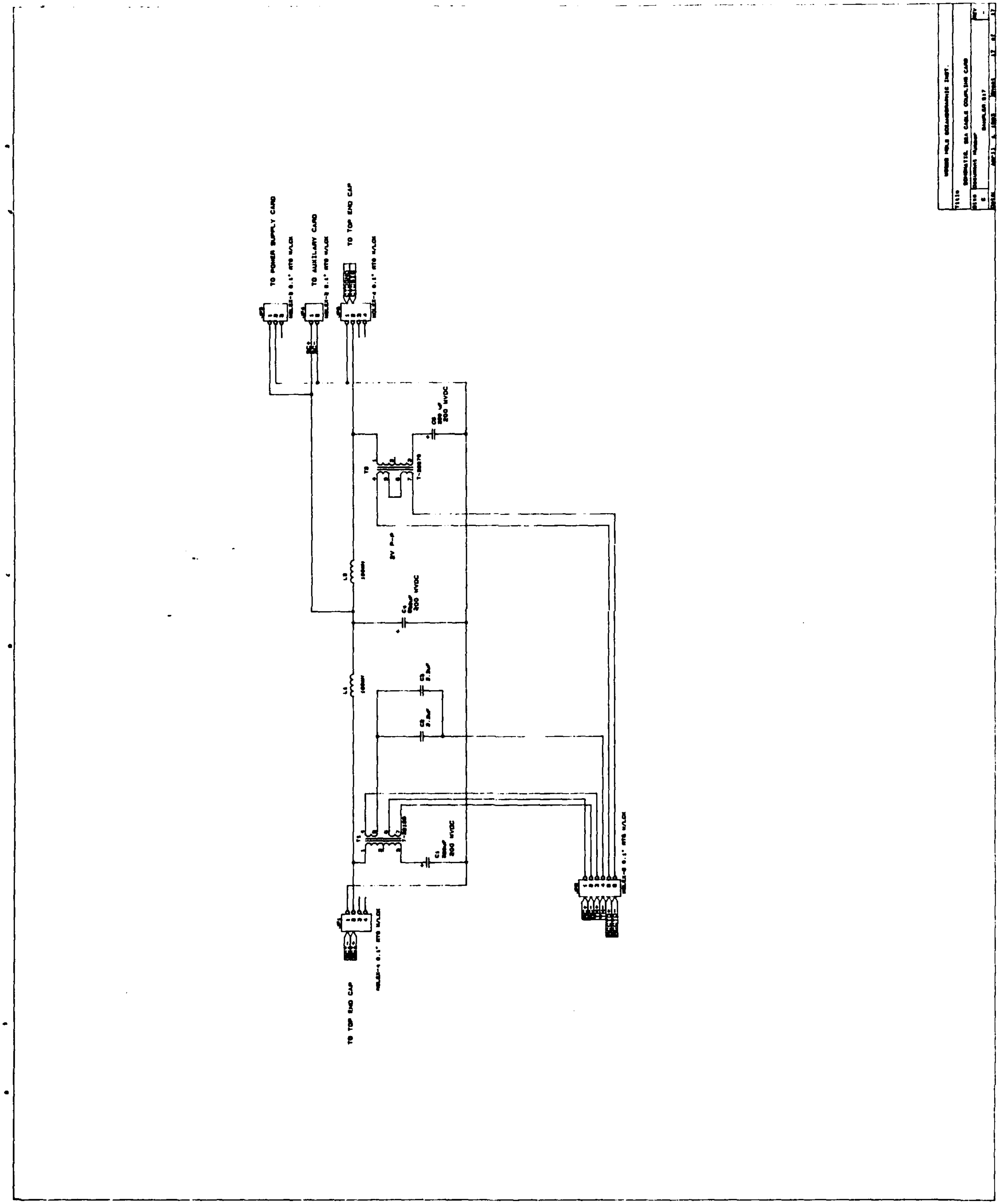


WOOD HOLE OCEANOGRAPHIC INST.			
Title PIGTAIL # 3, ROTARY VALVE			
Size B	Document Number RVCABLE.SCH		REV 1
Date: April 7, 1993	Sheet 1 of 1		

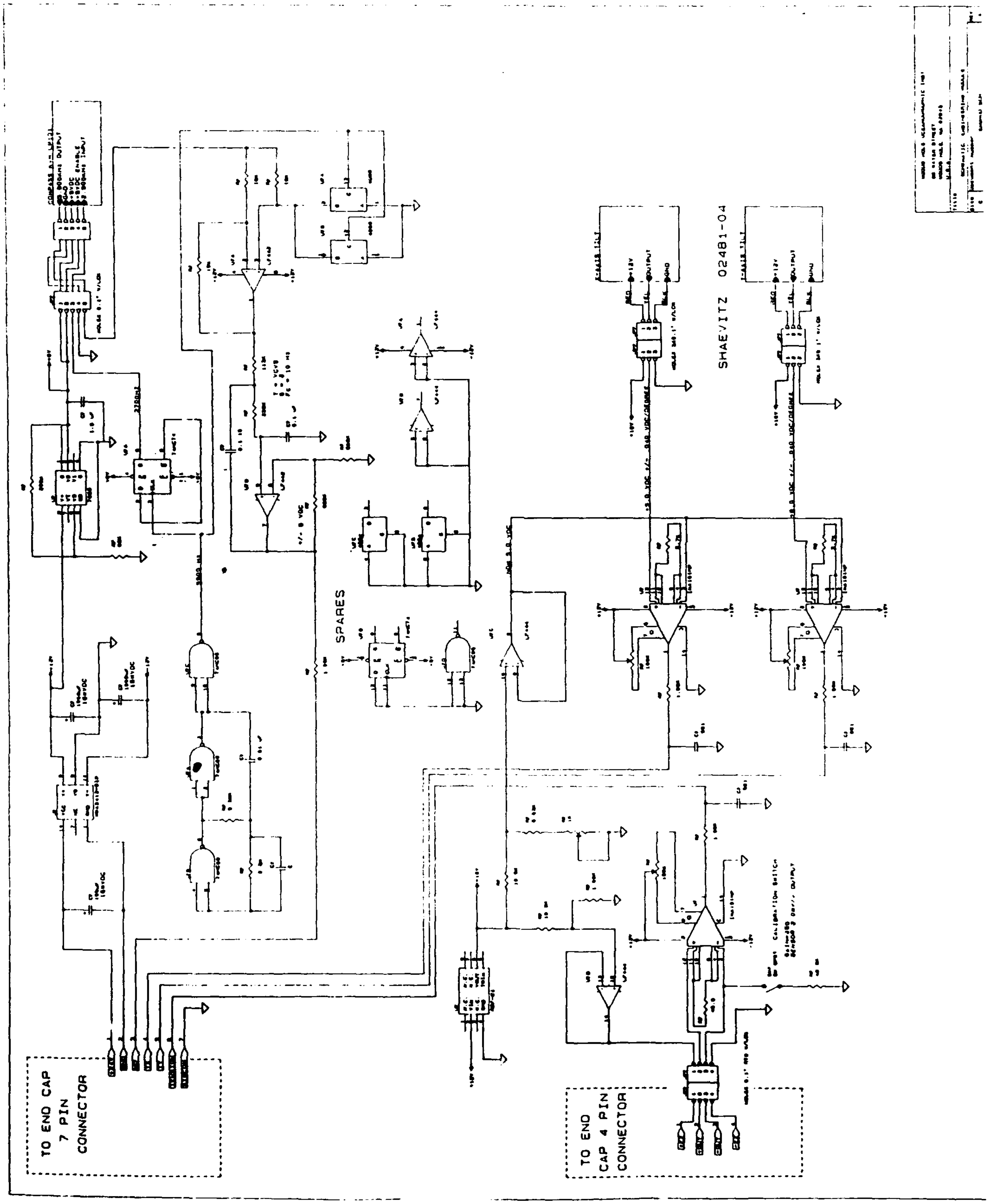


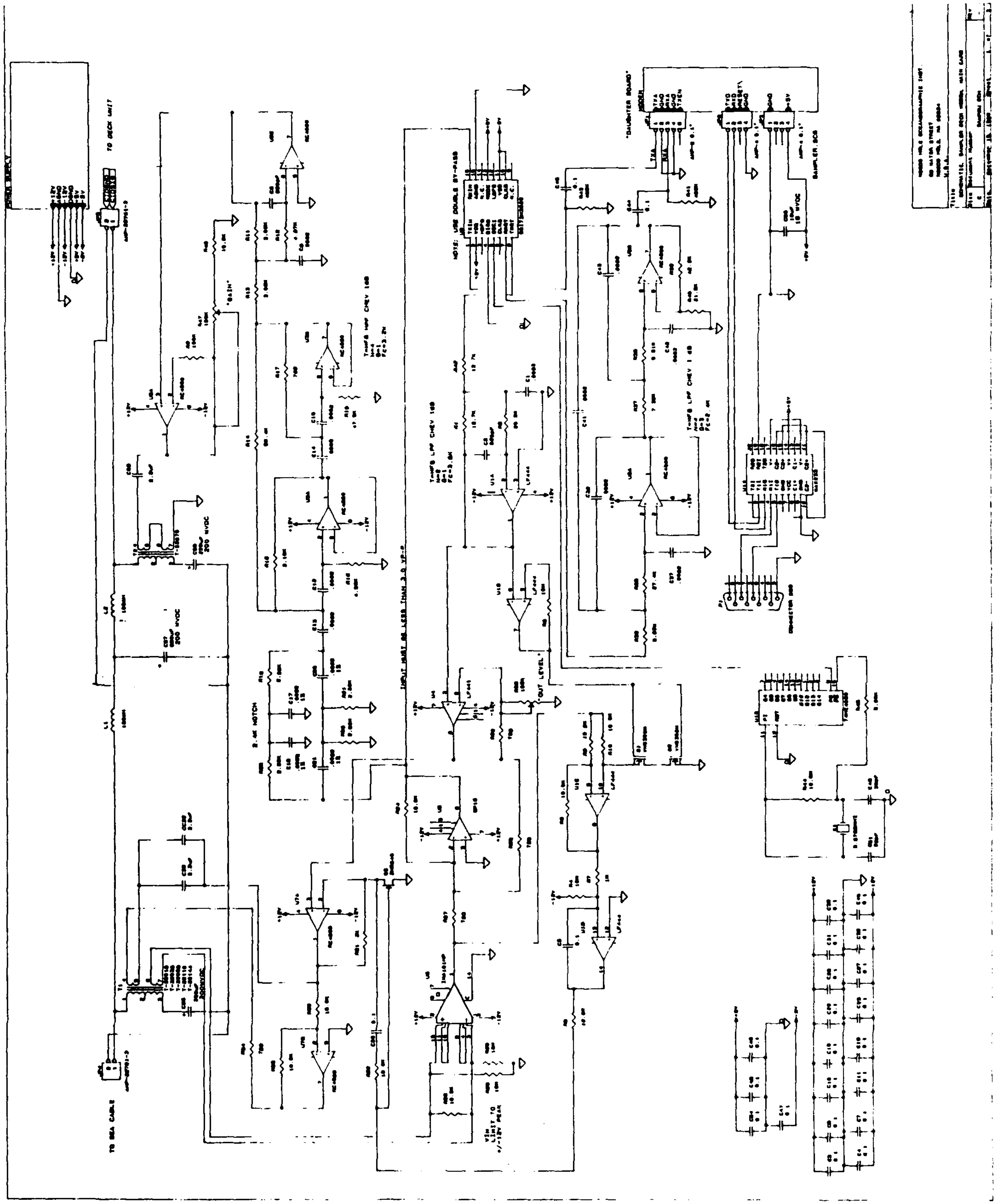
WOOD HOLE OCENAOGRAPHIC INST.		
Title SCHEMATIC, ROTARY VALVE HOUSING		
Size A	Document Number SAMPLER.SC7	REV 1
Date: February 20, 1990	Sheet 7 of 7	

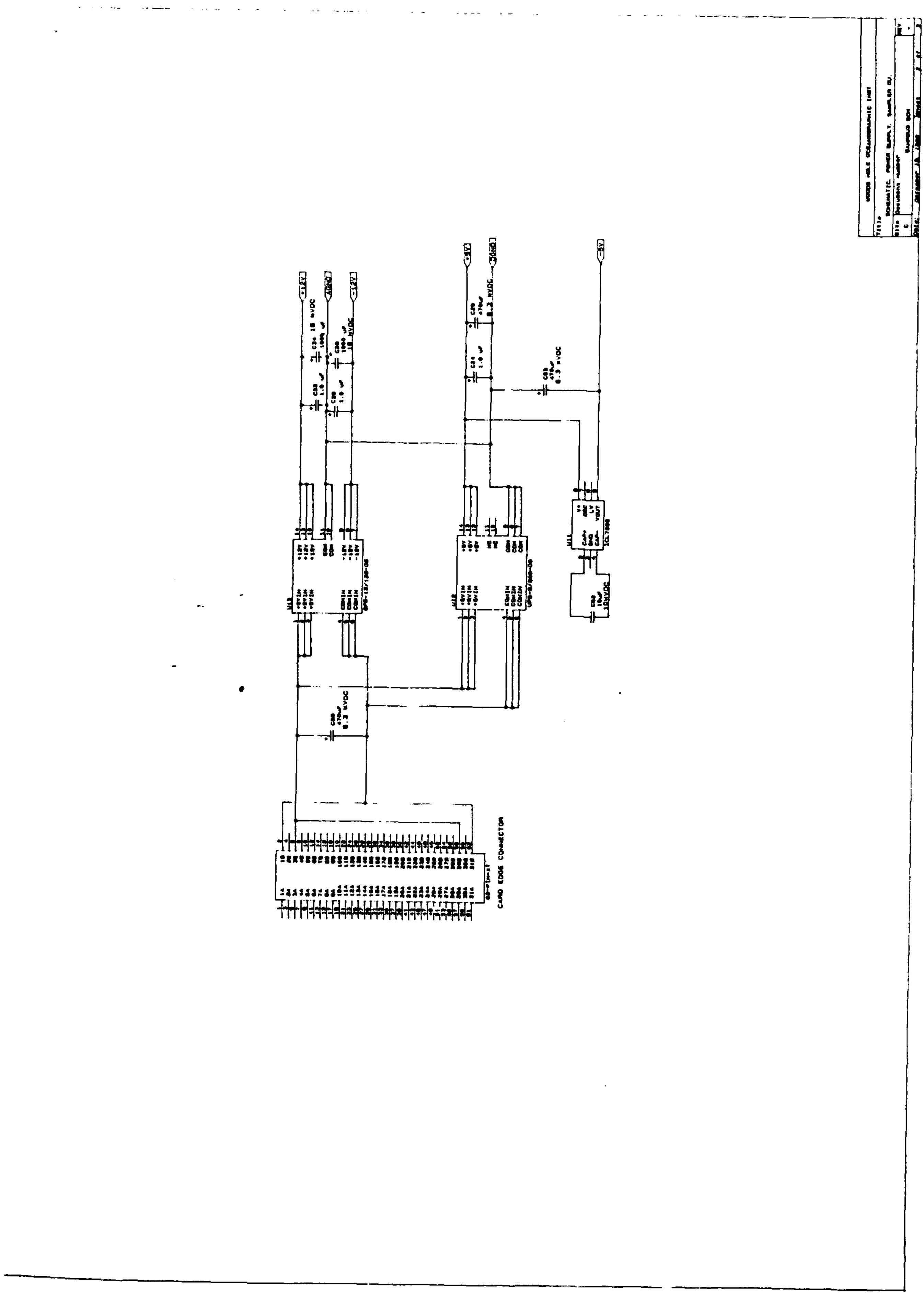


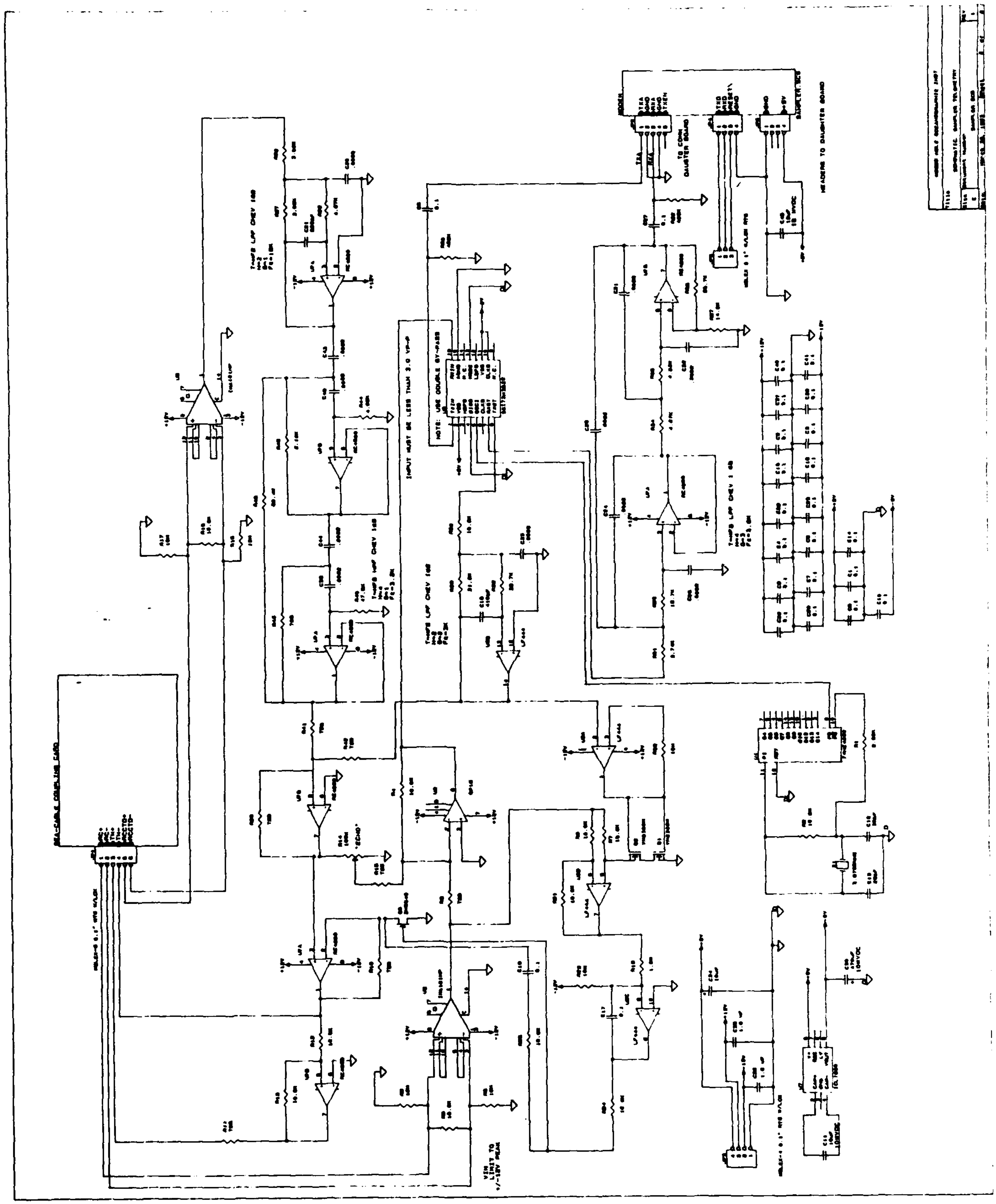


SCHEMATIC, SEA CABLE COUPLING CARD
TO POWER SUPPLY CARD
TO AUXILIARY CARD
TO TOP END CAP
TO TOP END CAP
200 WVDC
200 WVDC
200 WVDC
T1
T2
L1
L2
C1
C2
C3
C4
C5


SHAEVITZ 02481-04
SPARES
TO END CAP 7 PIN CONNECTOR
TO END CAP 4 PIN CONNECTOR

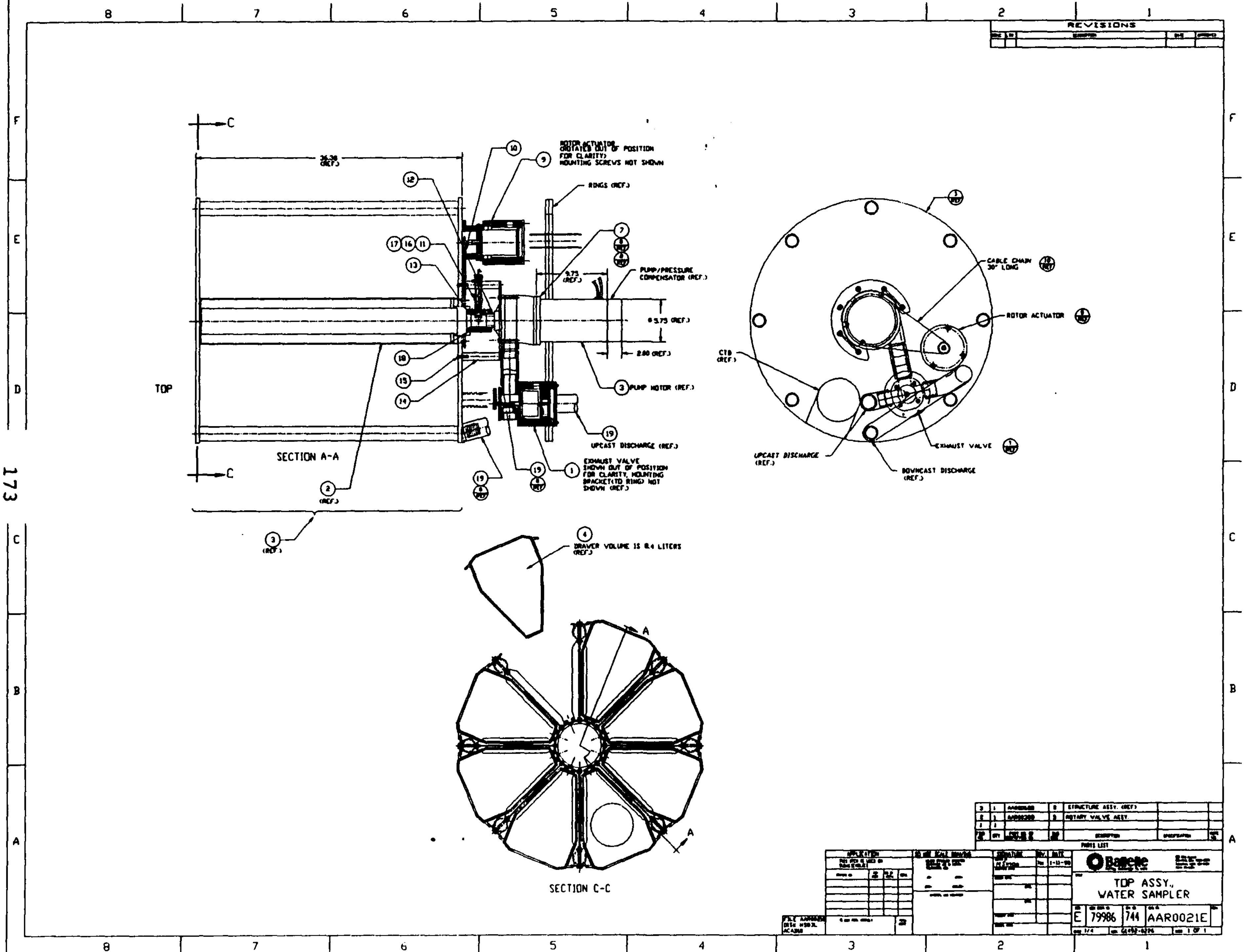


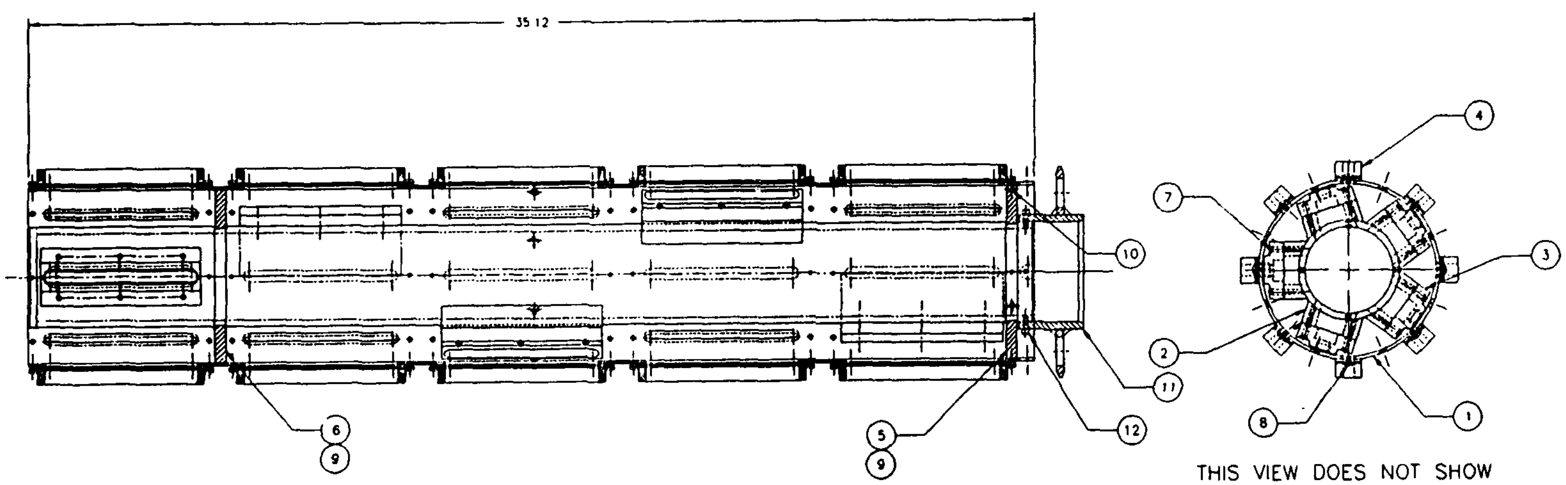

+12V
AGND
-12V
+5V
GND
-5V
ICL7660
CARD EDGE CONNECTOR



B: Mechanical Drawings (Battelle)

Drawing List for Water Acquisition System	
Description	Drawing Number
Water Acquisition System	AAR0021C
Rotary Valve Assembly	AAR0038D
Fixed Tube	AAR0035D
Rotor	AAR0036D
Fixed Branch	AAR0037C
Upper Spider	AAR0042C
Sprocket	AAR0043C
Fixed Seal	AAR0047C
Floating Seal	AAR0173C
Exhaust Valve Assembly	AAR0050C
Exhaust Valve Body	AAR0051D
Valve Spool	AAR0052C
Exhaust Valve Body	AAR0053D
Valve Cover	AAR0054C
Exhaust Valve Motor Cover	AAR0055C
Rotary Valve Motor	AAR0057D
Rotary Valve Motor End Cap	AAR0056D
Motor Body Cover	AAR0055C
Rotary Valve Motor Body	AAR0060D
Aux. Shaft	AAR0061B
Pump Plate	AAR0044C
Adapter	AAR0045C
Flowmeter Assembly	AAR0063C
Shaft Mount	AAR0064C
Housing	AAR0065C
Retainer Coil	AAR0066C
Plug	AAR0067C
Shaft	AAR0074C
Ladder Assembly	AAR0071D
Ladder	AAR0034D
Clamp Plate	AAR0030D
Chock, Spacer	AAR0031B
Set Screw	AAR0068B
Home Position Switch Assembly	AAR0078D
Rotary Valve Plug	AAR0073C
Rotary Valve Switch Body	AAR0070C
Fitting	AAR0076B
Spring Retainer	AAR0072B
Switch Mount	AAR0075C
Switch Plunger	AAR0074B
Adjusting Screw	AAR0077B
Drawer Assembly	AAR0033D
Poppet Valve Assembly	AAR0080C
Valve Body	AAR0081C
Poppet Valve	AAR0082C
Bag	AAR0084D
Sample Extraction Probe	AAR0085B


REVISIONS
ROTOR ACTUATOR (ROTATED OUT OF POSITION FOR CLARITY) MOUNTING SCREWS NOT SHOWN
RINGS (REF.)
36.38 (REF.)
9.75 (REF.)
PUMP/PRESSURE COMPENSATOR (REF.)
Ø 5.75 (REF.)
2.80 (REF.)
PUMP MOTOR (REF.)
UPCAST DISCHARGE (REF.)
EXHAUST VALVE SHOWN OUT OF POSITION FOR CLARITY, MOUNTING BRACKET(TO RING) NOT SHOWN (REF.)
TOP
SECTION A-A
C
DRAWER VOLUME IS 8.4 LITERS (REF.)
A
SECTION C-C
CABLE CHAIN 30" LONG
ROTOR ACTUATOR
CTD (REF.)
EXHAUST VALVE
UPCAST DISCHARGE (REF.)
DOWNCAST DISCHARGE (REF.)
STRUCTURE ASSY. (REF)
ROTARY VALVE ASSY.
PARTS LIST
Battelle
TOP ASSY., WATER SAMPLER
E 79986 744 AAR0021E



THIS VIEW DOES NOT SHOW SPIDERS AND SPROCKET

FIND NO	QTY	PART NO. OR IDENTIFYING NO.	DWG SIZE	DESCRIPTION	SPECIFICATION	NOTE NO
12	4	#8-32 X .50		SOCKET HD. SCREW	STAINLESS	
11	1	AAR0041C	C	SPROCKET		
10	4	#8-32 X .50		FLAT HD. SCREW	STAINLESS	
9	4	#8-32 X 1.0		SOCKET HD. SCREW	STAINLESS	
8	80	#6-32 X .25		PAN HEAD SCREW	STAINLESS	
7	30	#8-32 X 1.0		FLAT HEAD SCREW(82°)	STAINLESS	
6	1	AAR0042C	C	UPPER SPIDER		
5	1	AAR0041C	C	LOWER SPIDER		
4	40	AAR0040C	C	FIXED SEAL		
3	8	AAR0037C	C	SEAL HOLDER		
2	1	AAR0035D	D	ROTOR		
1	1	AAR0035D	D	FIXED TUBE		

PARTS LIST

APPLICATION

THIS ITEM IS USED ON SUBASSEMBLIES

AAR0021E 1

AAR0021E 1

DO NOT SCALE DRAWING

SIGNATURE: M. Simon | DIV: 744 | DATE: 11-30-89

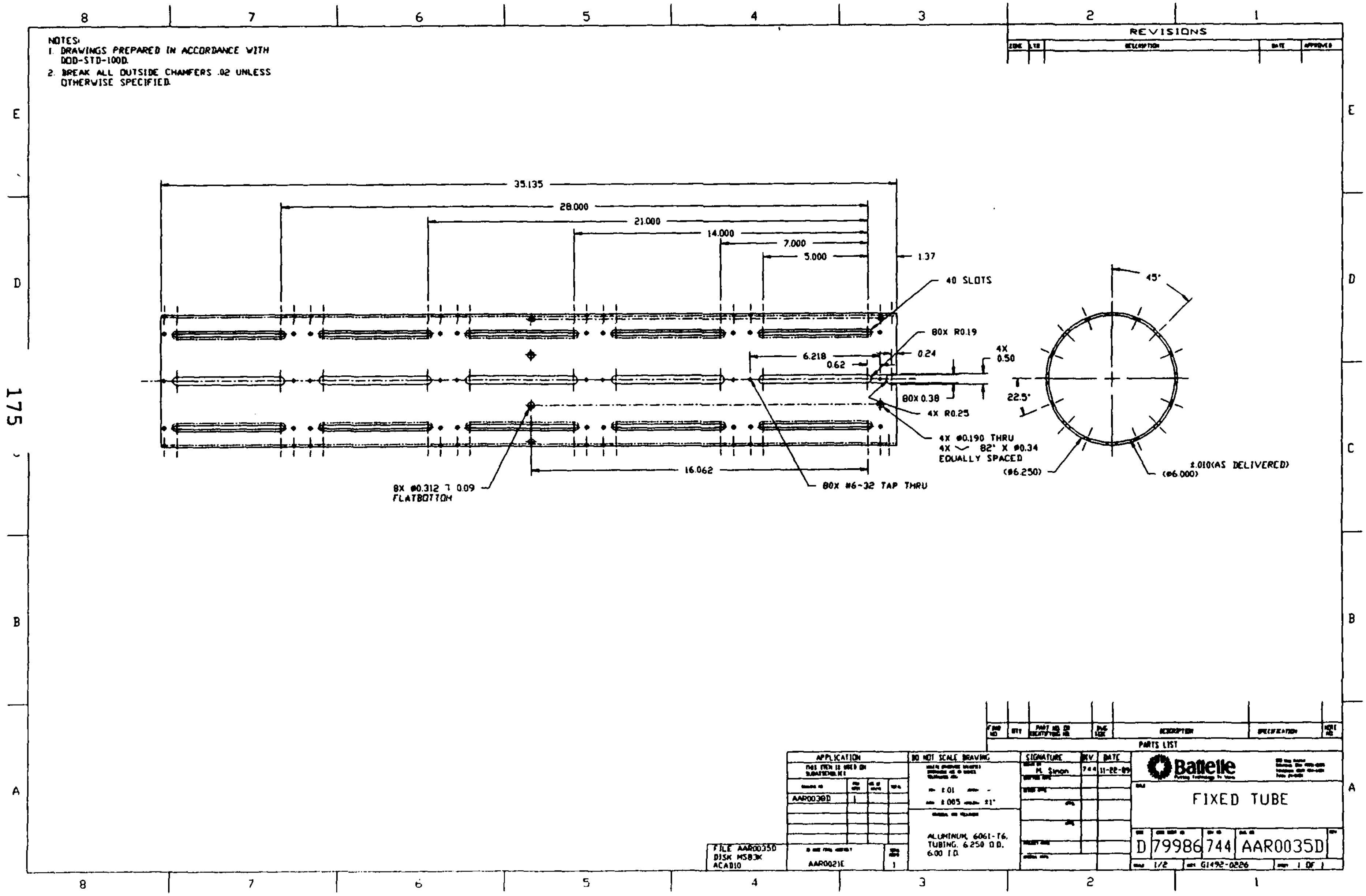
Battelle

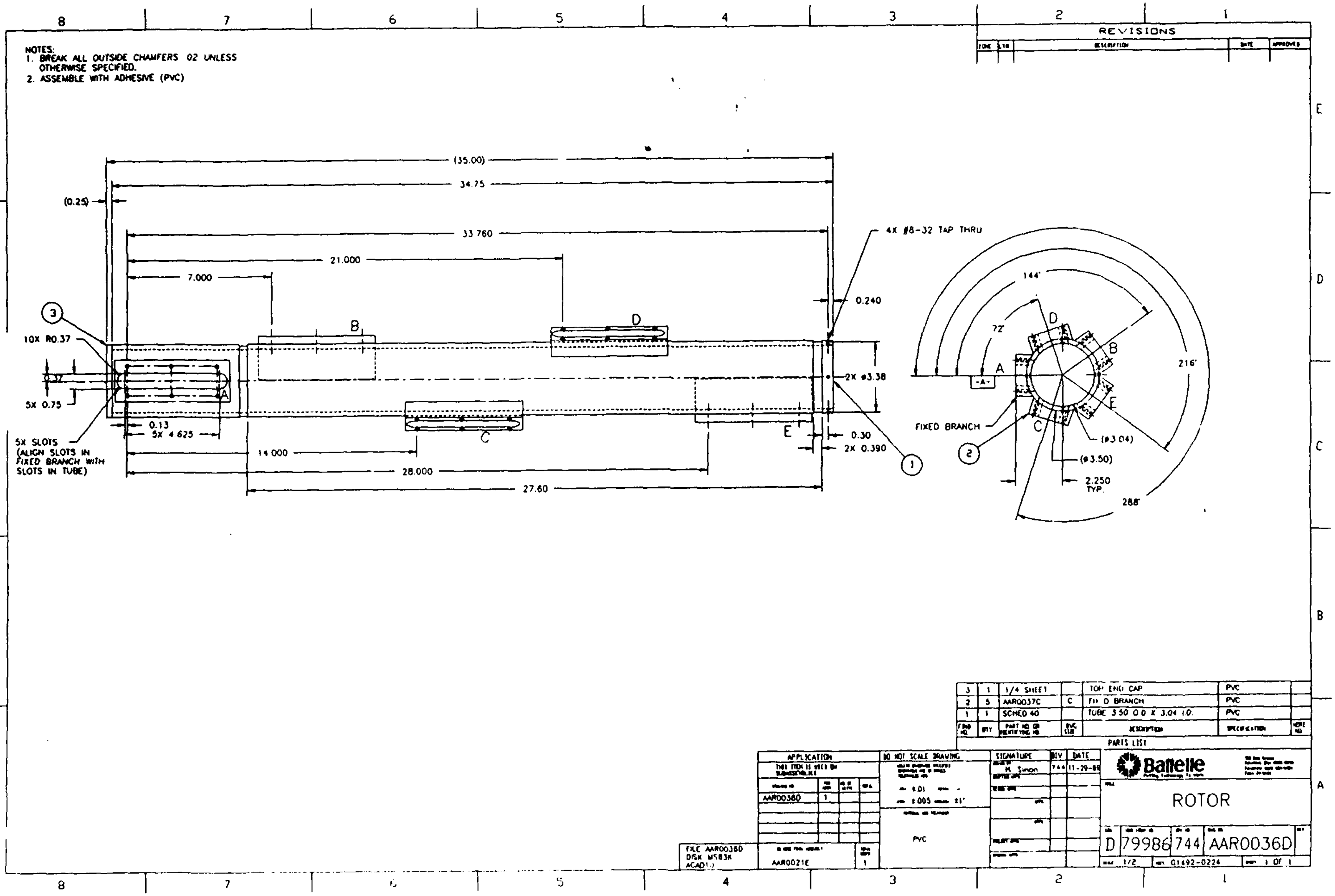
ROTARY VALVE ASSEMBLY

D | 79986 | 744 | AAR0038D

1/2 | G1492-0228 | 1 OF 1

FILE AAR0038D
DISK MS83K
ACAD10

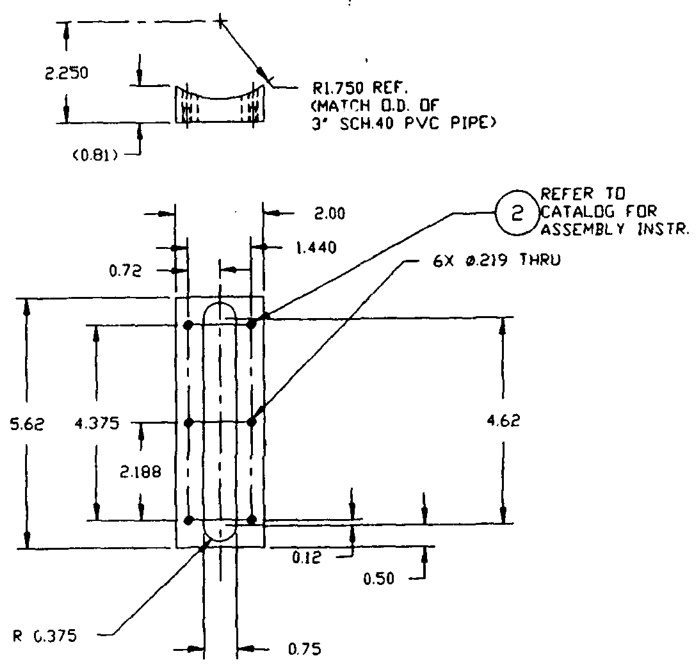

NOTES:
1. DRAWINGS PREPARED IN ACCORDANCE WITH DOD-STD-100D.
2. BREAK ALL OUTSIDE CHAMFERS .02 UNLESS OTHERWISE SPECIFIED.
REVISIONS
35.135
28.000
21.000
14.000
7.000
5.000
1.37
40 SLOTS
80X R0.19
6.218
0.24
0.62
4X 0.50
80X 0.38
4X R0.25
4X ⌀0.190 THRU
4X ⌵ 82° X ⌀0.34
EQUALLY SPACED
16.062
8X ⌀0.312 ↧ 0.09
FLATBOTTOM
80X #6-32 TAP THRU
45°
22.5°
(⌀6.250)
±.010(AS DELIVERED)
(⌀6.000)
PARTS LIST
APPLICATION
AAR0030D
AAR0021E
DO NOT SCALE DRAWING
±.01
±.005 ±1°
ALUMINUM, 6061-T6, TUBING, 6.250 O.D. 6.00 I.D.
SIGNATURE
M. Simon
REV DATE
744 11-22-89
Battelle
FIXED TUBE
D 79986 744 AAR0035D
1/2
G1492-0226
1 OF 1
FILE AAR0035D
DISK MSB3K
ACAB10


NOTES:
1. BREAK ALL OUTSIDE CHAMFERS .02 UNLESS OTHERWISE SPECIFIED.
2. ASSEMBLE WITH ADHESIVE (PVC)
REVISIONS
(35.00)
34.75
(0.25)
33.760
21.000
7.000
4X #8-32 TAP THRU
0.240
10X R0.37
5X 0.75
5X SLOTS (ALIGN SLOTS IN FIXED BRANCH WITH SLOTS IN TUBE)
0.13
5X 4.625
14.000
28.000
27.60
2X ø3.38
0.30
2X 0.390
144°
72°
216°
288°
FIXED BRANCH
(ø3.04)
(ø3.50)
2.250 TYP.
1/4 SHEET | TOP END CAP | PVC
AAR0037C | C | FIXED BRANCH | PVC
SCHED 40 | TUBE 3.50 O.D. X 3.04 I.D. | PVC
PARTS LIST
APPLICATION
AAR0038D
AAR0021E
DO NOT SCALE DRAWING
PVC
SIGNATURE
M. Simon
11-29-89
Battelle
ROTOR
D 79986 744 AAR0036D
1/2
G1492-0224
1 OF 1
FILE AAR0036D
DISK MS83K
ACAD

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES:
1. REMOVE BURRS AND BREAK SHARP EDGES .02.



FIND NO.	QTY	PART NO. OR IDENTIFYING NO.	DWG SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.
2	6	INS15/8-32/.313		THREADED INSERT	SPIROL	
1	1			FIXED BRANCH	PVC	

PARTS LIST

APPLICATION			
THIS ITEM IS USED ON SUBASSEMBLIES			
DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
AAR0036C	5		
TO MAKE FINAL ASSEMBLY			TOTAL REQ'D
AAP0021E			

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE:
xx= ±.01 xxxx= -
xxx= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
PVC

SIGNATURE	DIV	DATE
DRAWN BY M. Simon	744	11-29-89
DRAFTING APPD		
DESIGN APPD		
APPD		
APPD		
PROJECT APPD		
SPECIAL APPD		

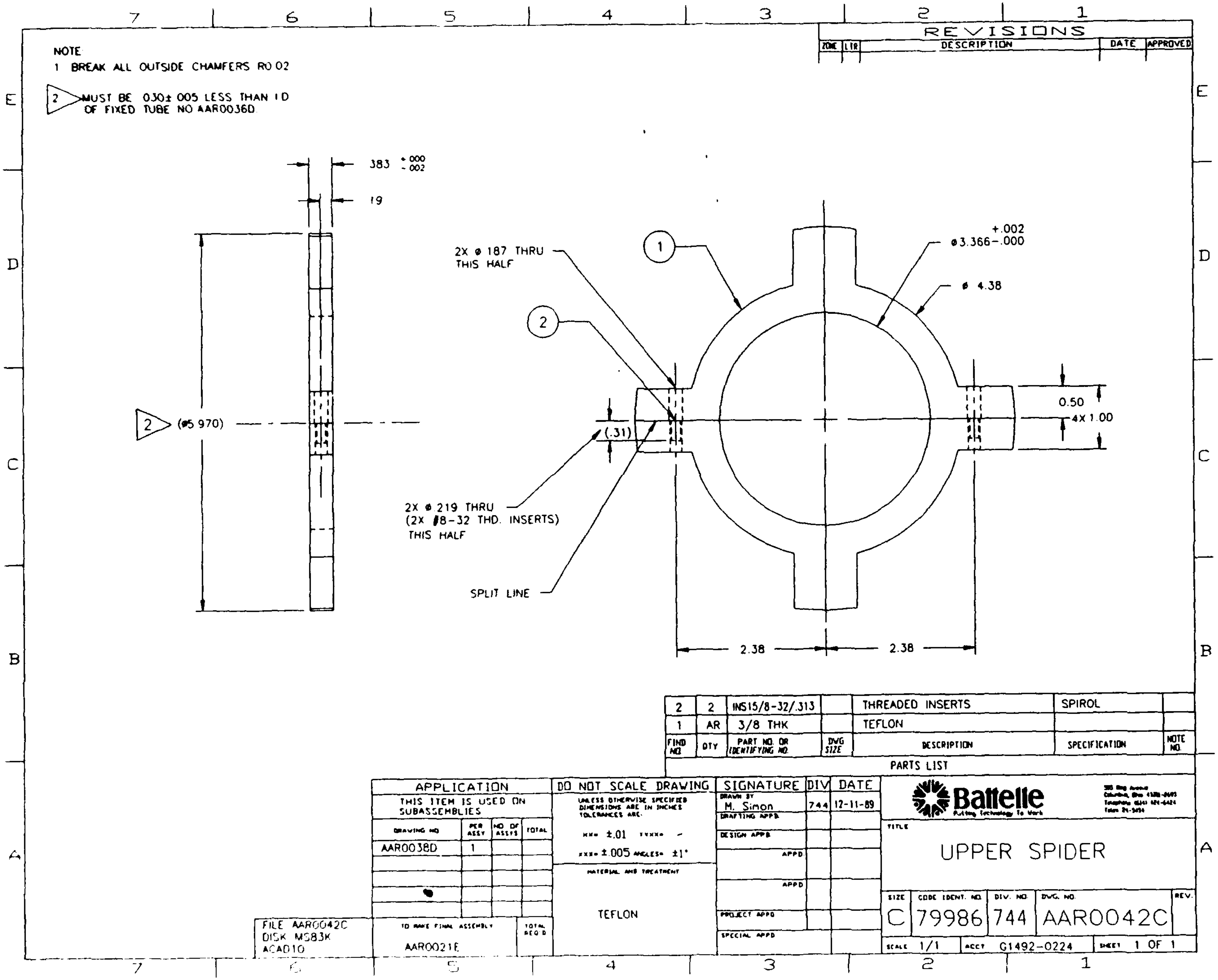
Battelle
Putting Technology To Work

TITLE
FIXED BRANCH

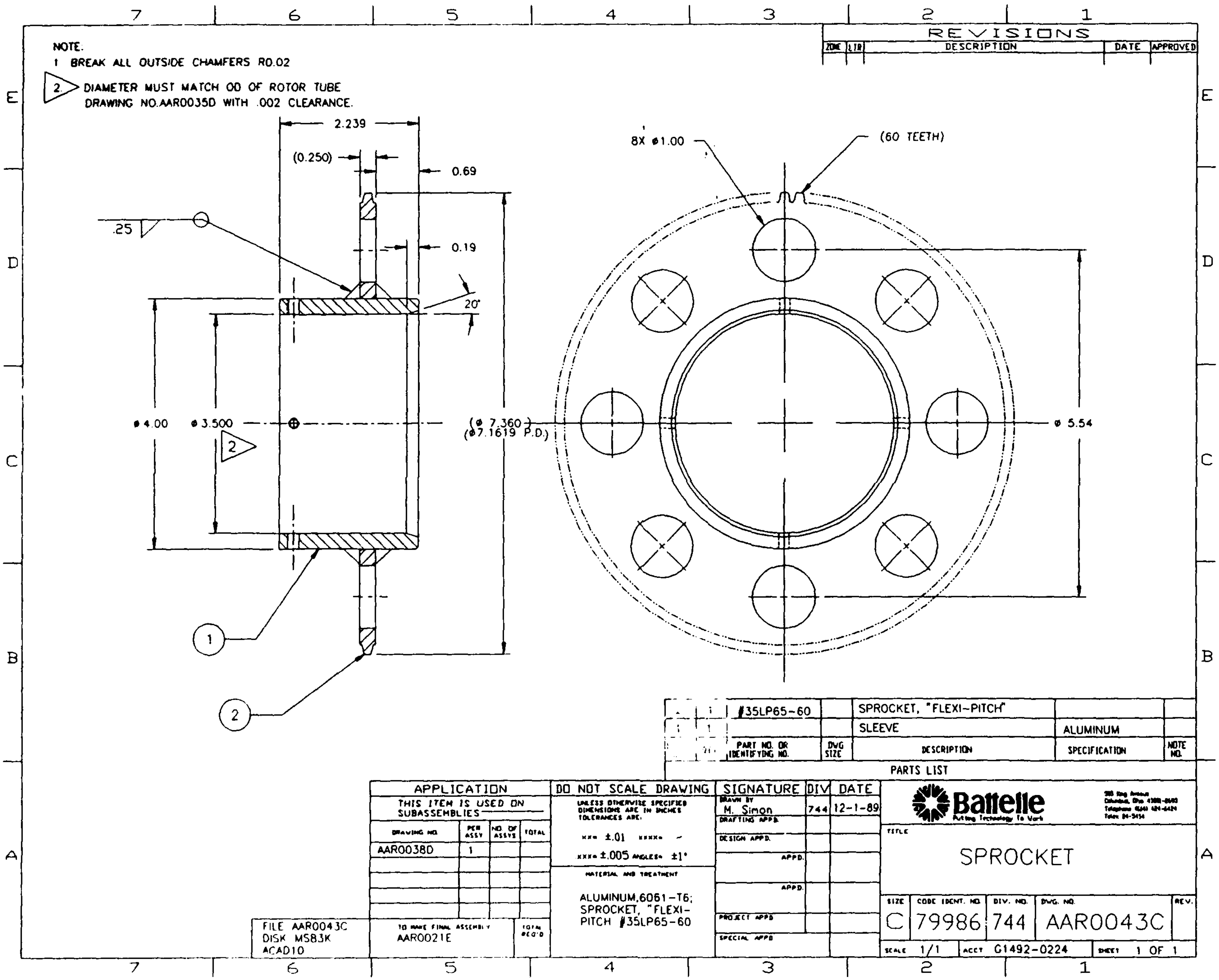
SIZE	CODE IDENT. NO.	DIV NO.	DWG. NO.	REV.
C	79986	744	AAR0037C	

SCALE 1/2 ACCT. G1492-0224 SHEET 1 OF 1

FILE AAR0037C
DISK MS83K
ACAD10



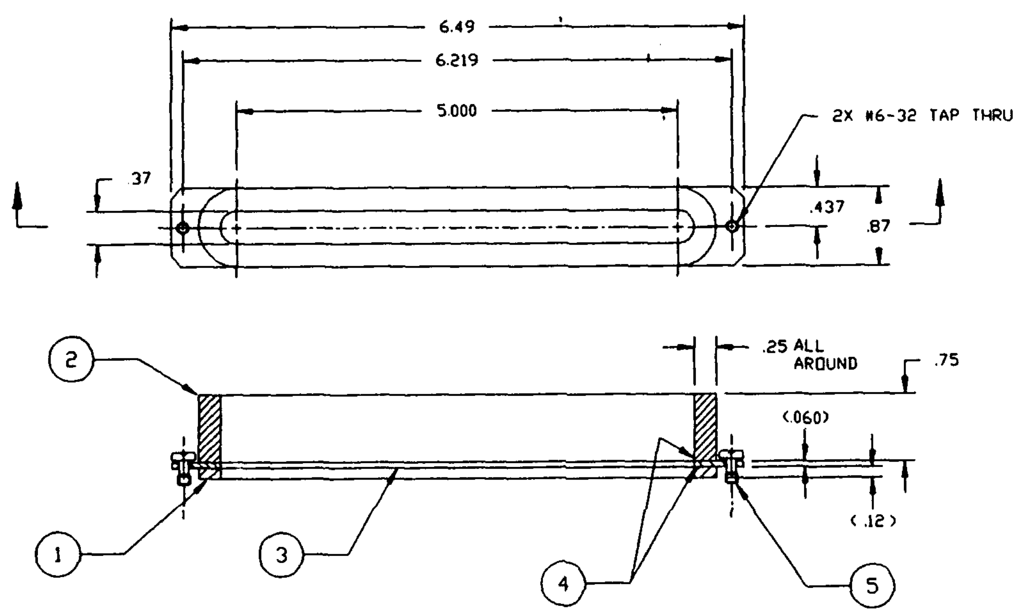
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
NOTE
1 BREAK ALL OUTSIDE CHAMFERS R0.02
2 MUST BE .030± .005 LESS THAN I.D. OF FIXED TUBE NO AAR0036D
383 +.000 -.002
19
(ø5.970)
2X ø.187 THRU THIS HALF
2X ø.219 THRU (2X #8-32 THD. INSERTS) THIS HALF
SPLIT LINE
(.31)
+.002 ø3.366-.000
ø 4.38
0.50
4X 1.00
2.38
2.38
2 | 2 | INS15/8-32/.313 | THREADED INSERTS | SPIROL
1 | AR | 3/8 THK | TEFLON
FIND NO. | QTY | PART NO. OR IDENTIFYING NO. | DWG SIZE | DESCRIPTION | SPECIFICATION | NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO | PER ASSY | NO. OF ASSYS | TOTAL
AAR0038D | 1
TO MAKE FINAL ASSEMBLY
AAR0021E
TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx= ±.01
.xxx= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
TEFLON
SIGNATURE DIV DATE
DRAWN BY M. Simon 744 12-11-89
DRAFTING APPD
DESIGN APPD
APPD
APPD
PROJECT APPD
SPECIAL APPD
Battelle
Putting Technology To Work
TITLE
UPPER SPIDER
SIZE C
CODE IDENT. NO. 79986
DIV. NO. 744
DWG. NO. AAR0042C
REV.
SCALE 1/1
ACCT G1492-0224
SHEET 1 OF 1
FILE AAR0042C
DISK MS83K
ACAD10


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
NOTE:
1 BREAK ALL OUTSIDE CHAMFERS R0.02
2 DIAMETER MUST MATCH OD OF ROTOR TUBE DRAWING NO.AAR0035D WITH .002 CLEARANCE.
2.239
(0.250)
0.69
0.19
20°
.25
8X ø1.00
(60 TEETH)
ø 4.00
ø 3.500
(ø 7.360)
(ø7.1619 P.D.)
ø 5.54
1
2
#35LP65-60
SPROCKET, "FLEXI-PITCH"
SLEEVE
ALUMINUM
PART NO. OR IDENTIFYING NO.
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO.
PER ASSY
NO. OF ASSYS
TOTAL
AAR0038D
1
TO MAKE FINAL ASSEMBLY
AAR0021E
TOTAL REQ'D
FILE AAR0043C
DISK MS83K
ACAD10
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx= ±.01
.xxx= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
ALUMINUM,6061-T6; SPROCKET, "FLEXI-PITCH #35LP65-60
SIGNATURE
DRAWN BY
M. Simon
DRAFTING APPD.
DESIGN APPD.
APPD.
APPD.
PROJECT APPD
SPECIAL APPD
DIV
744
DATE
12-1-89
Battelle
Putting Technology To Work
TITLE
SPROCKET
SIZE
C
CODE IDENT. NO.
79986
DIV. NO.
744
DWG. NO.
AAR0043C
REV.
SCALE 1/1
ACCT G1492-0224
SHEET 1 OF 1

NOTE:
BREAK ALL OUTSIDE CHAMFERS R0.02

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED



FIND NO.	QTY	PART NO. OR IDENTIFYING NO.	DWG SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.
5	2	AAR0049B	B	CAPTIVE SCREW		
4	AR			ADHESIVE		
3	AR	.06 THK.		STAINLESS		
2	AR	3/4 THK		OPEN CELL NEOPRENE		
1	AR	1/8 THK		OPEN CELL NEOPRENE		

PARTS LIST

APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES

DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
AAR0038D	40		

TO MAKE FINAL ASSEMBLY: AAR0021E — TOTAL REQ'D

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx = ±.01 .xxxx = ~
.xxx = ±.005 ANGLES = ±1°
MATERIAL AND TREATMENT
SEE ABOVE

SIGNATURE	DIV	DATE
DRAWN BY M. Simon	744	12-12-89
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

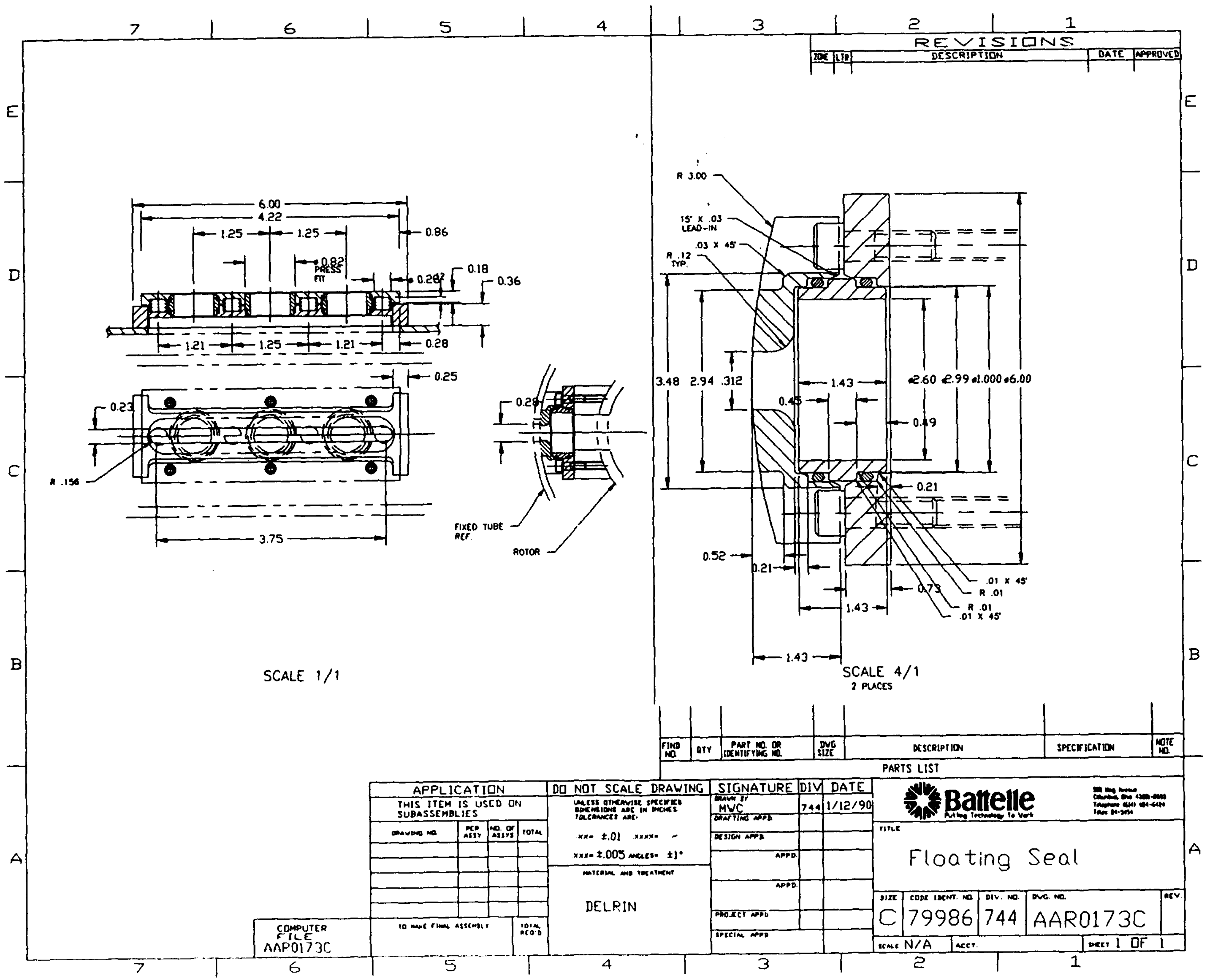
Battelle
Putting Technology To Work

TITLE: FIXED SEAL

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
C	79986	744	AAR0047C	

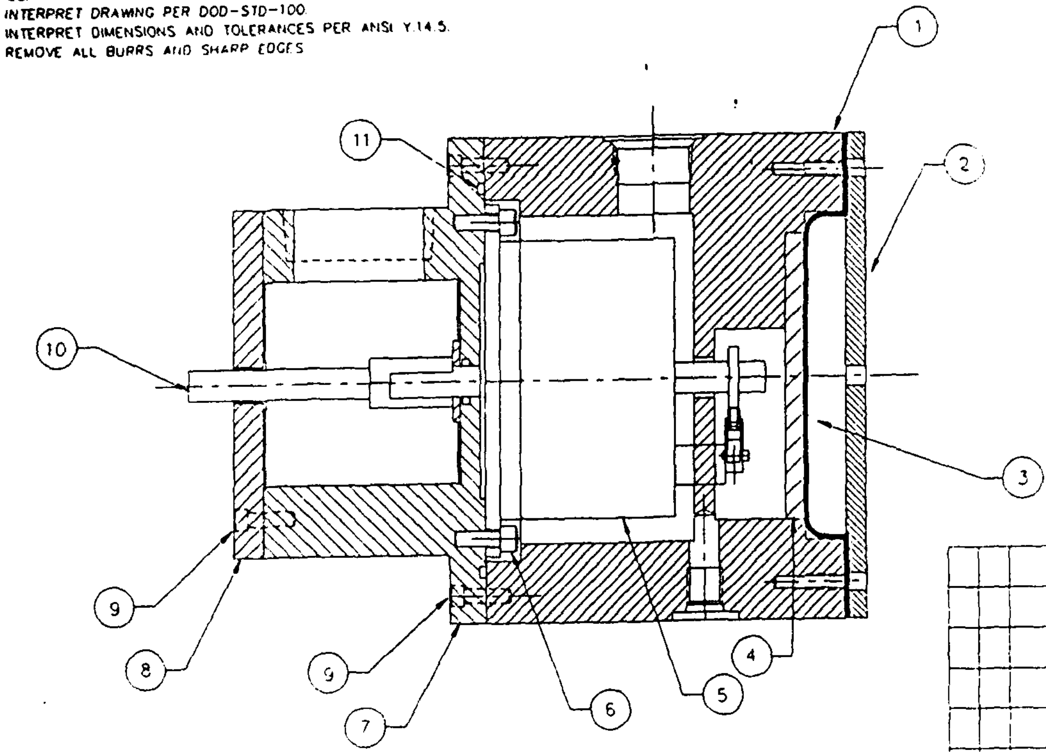
SCALE 1/1 ACCT G1492-0224 SHEET 1 OF 1

FILE AAR0047C
DISK MS83K
ACAD10



REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
R 3.00
15° X .03 LEAD-IN
.03 X 45°
R .12 TYP.
3.48 2.94 .312
1.43
0.45
0.49
⌀2.60 ⌀2.99 ⌀1.000 ⌀6.00
0.21
0.52
0.73
.01 X 45°
R .01
SCALE 4/1
2 PLACES
6.00
4.22
1.25
0.86
0.82 PRESS FIT
0.28
0.18
0.36
1.21
0.25
0.23
R .156
3.75
FIXED TUBE REF.
ROTOR
SCALE 1/1
FIND NO. QTY PART NO. OR IDENTIFYING NO. DWG SIZE DESCRIPTION SPECIFICATION NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO. PER ASSY NO. OF ASSYS TOTAL
TO MAKE FINAL ASSEMBLY TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE:
.XX= ±.01 .XXXX= -
.XXX= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
DELRIN
SIGNATURE DIV DATE
DRAWN BY MWC 744 1/12/90
DRAFTING APPD
DESIGN APPD
APPD.
APPD.
PROJECT APPD
SPECIAL APPD
Battelle
Putting Technology To Work
TITLE
Floating Seal
SIZE C
CODE IDENT. NO. 79986
DIV. NO. 744
DWG. NO. AAR0173C
REV.
SCALE N/A
ACCT.
SHEET 1 OF 1
COMPUTER FILE AAP0173C

NOTES:
1. INTERPRET DRAWING PER DOD-STD-100.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ANSI Y.14.5.
3. REMOVE ALL BURRS AND SHARP EDGES



PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	ITEM NO
	O-RING		11
AAR0052C	SPOOL		10
	SCREW, SKT HD CAP 10-24		9
AAR0054C	VALVE COVER		8
AAR0051D	EXHAUST VALVE BOD		7
	SCREW, SKT HD CAP 10-24		6
	MOTOR		5
AAR0058B	SWITCH COVER		4
	BLADDER(PURCHASED)		3
AAR0055C	EXHAUST VALVE MOTOR COVER		2
AAR0053D	EXHAUST VALVE MOTOR COVER		1

PARTS LIST

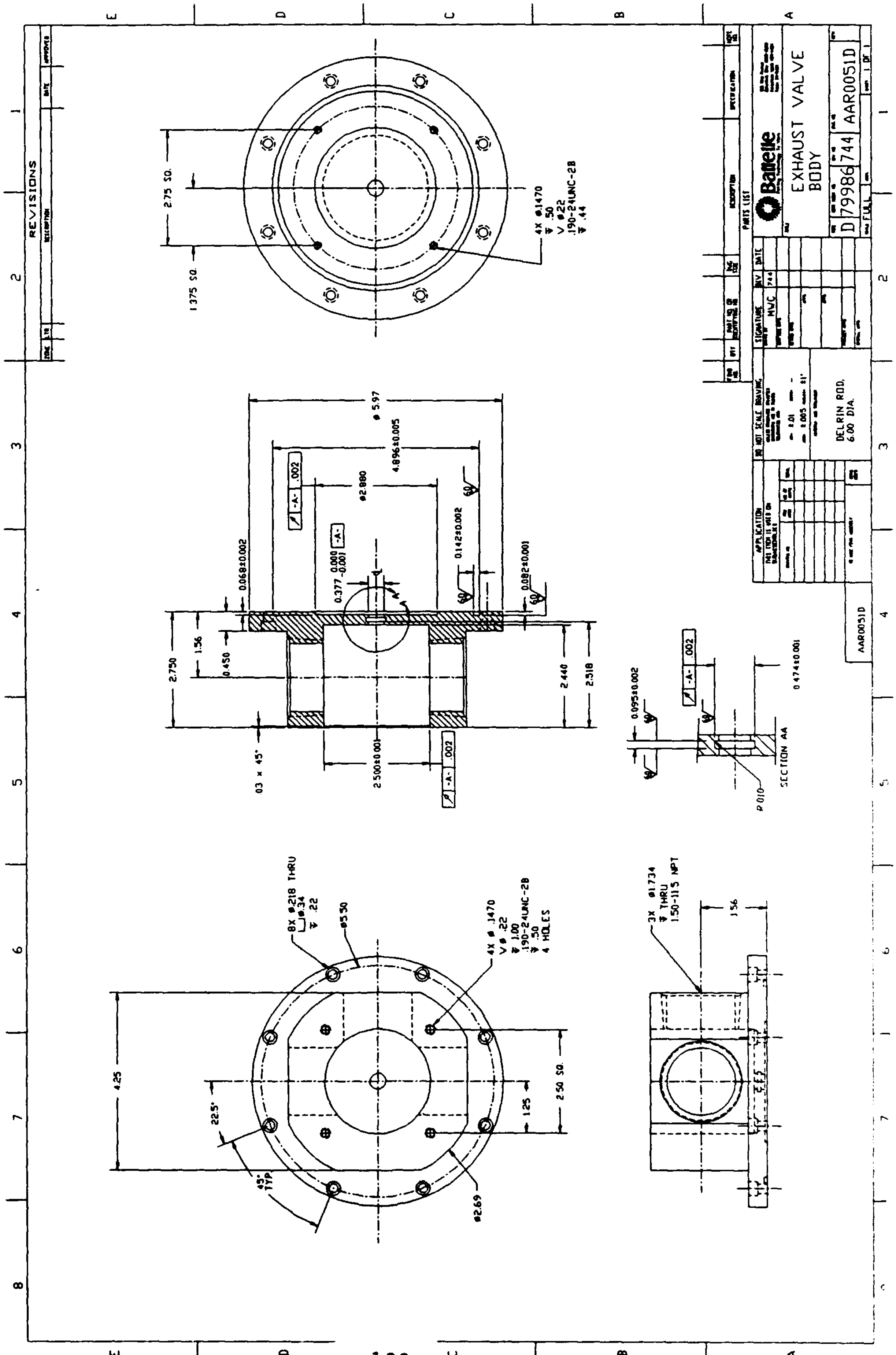
Battelle

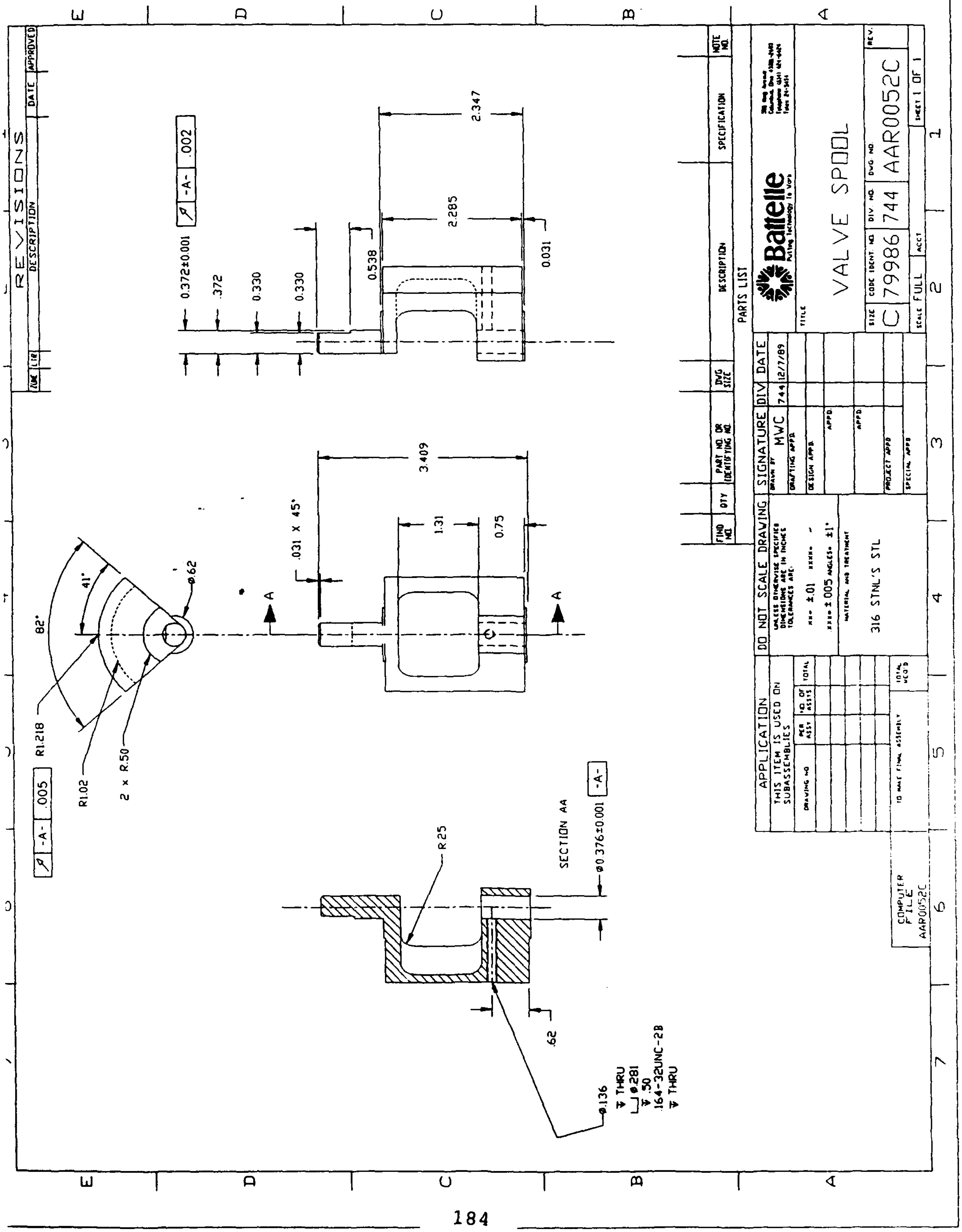
EXHAUST VALVE ASSEMBLY

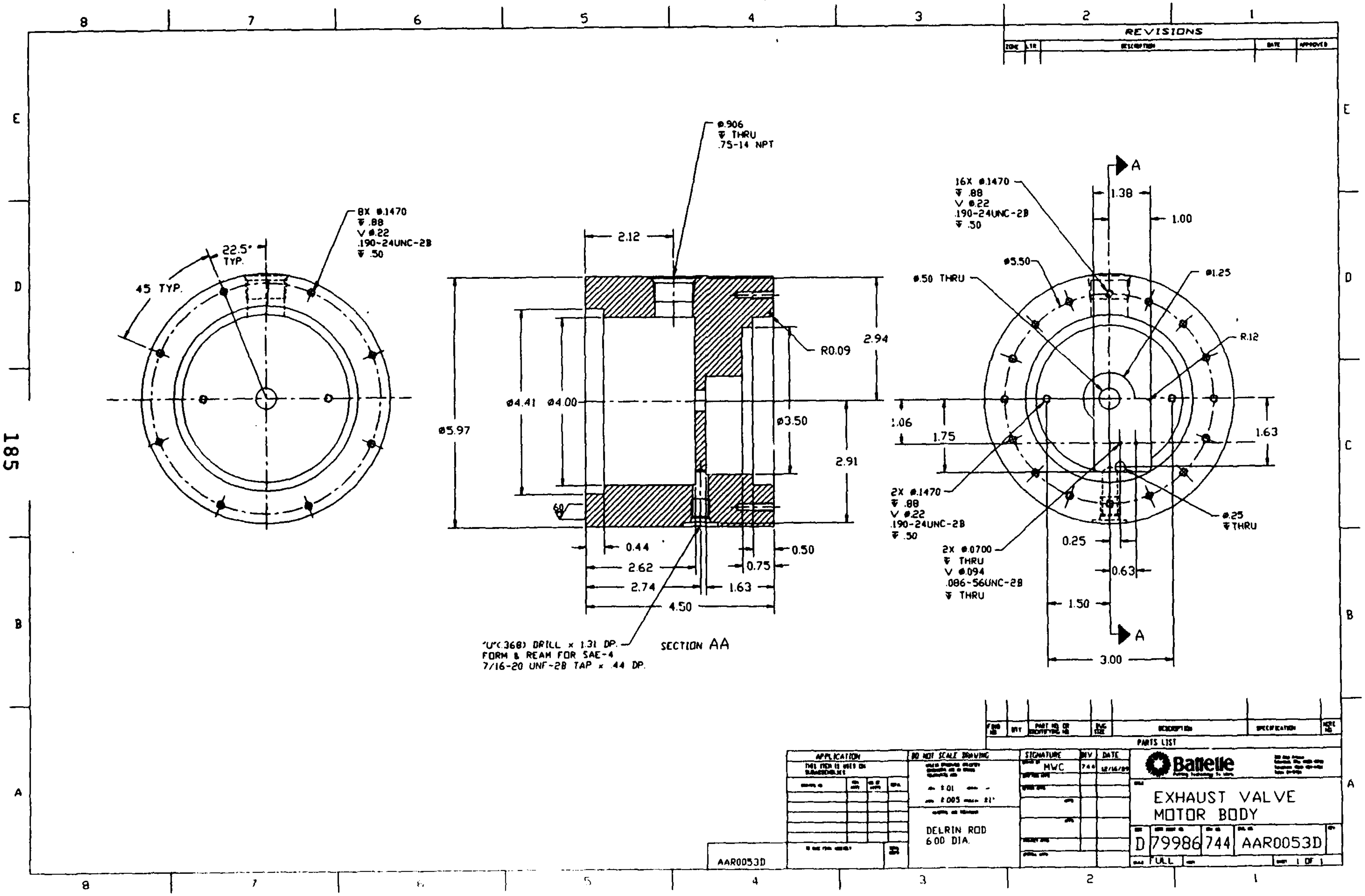
79986 AAR0050C

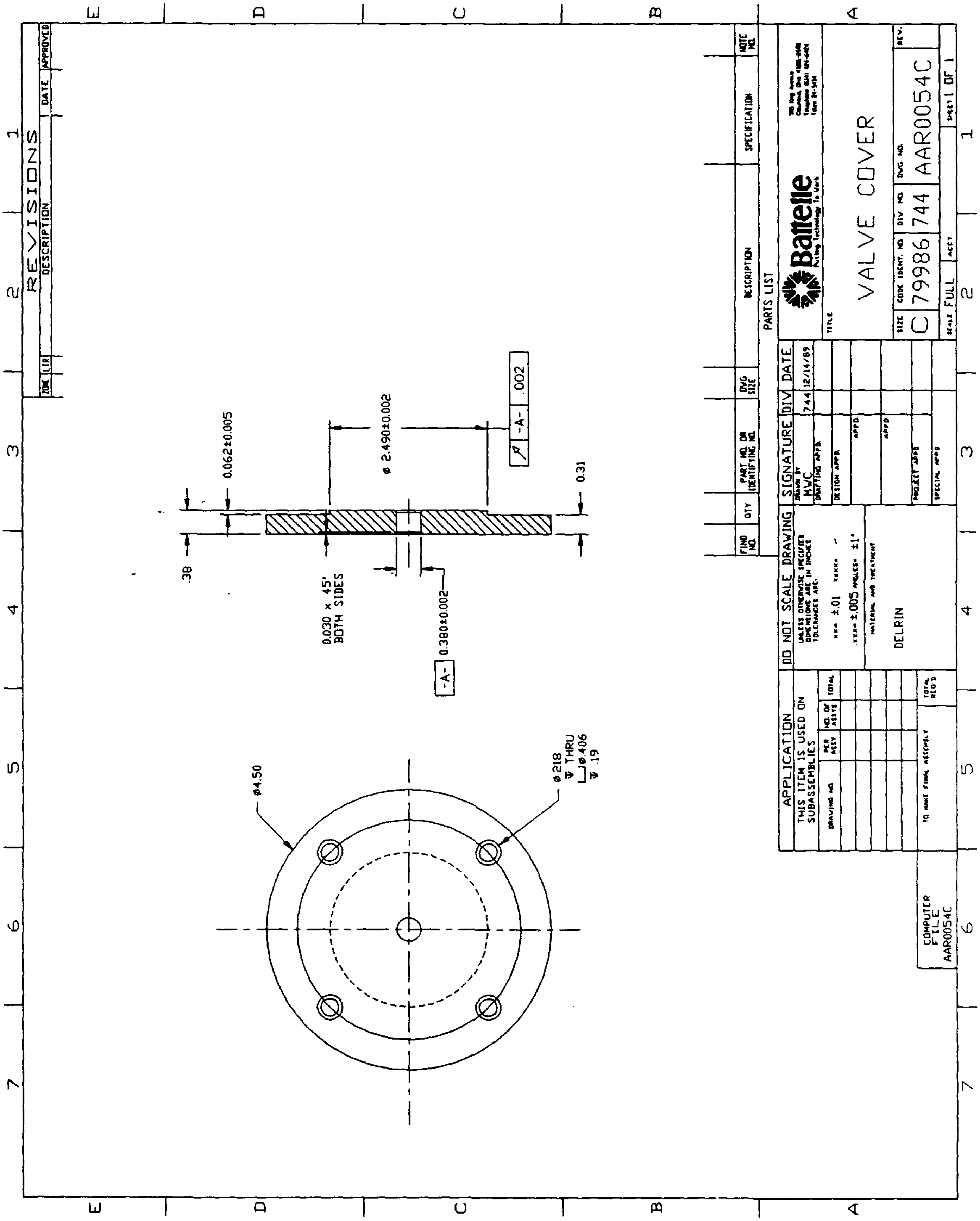
SCALE 1/1 SHEET 1 OF 1

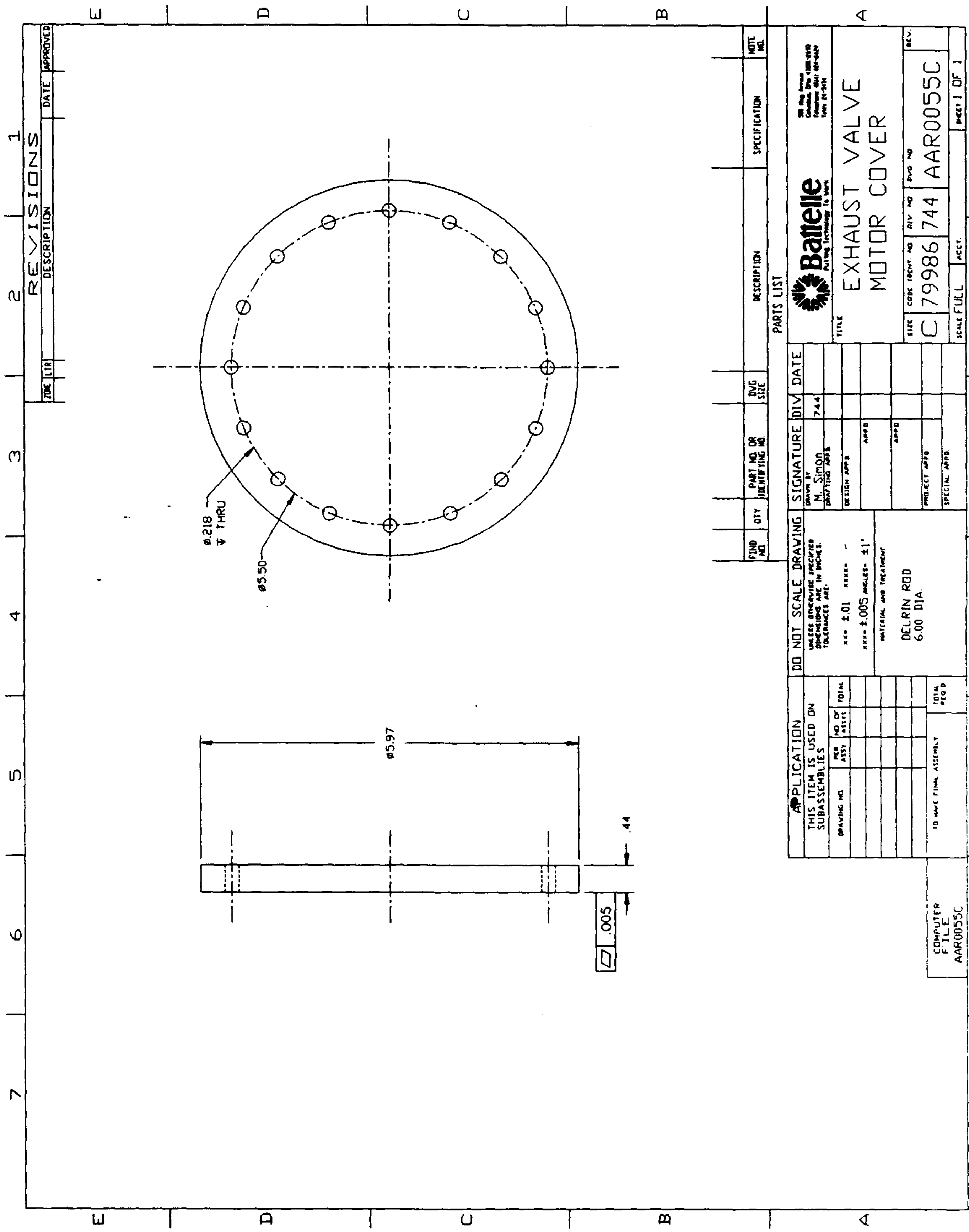
COMPUTER FILE NO AAR0050C DISK 8.14

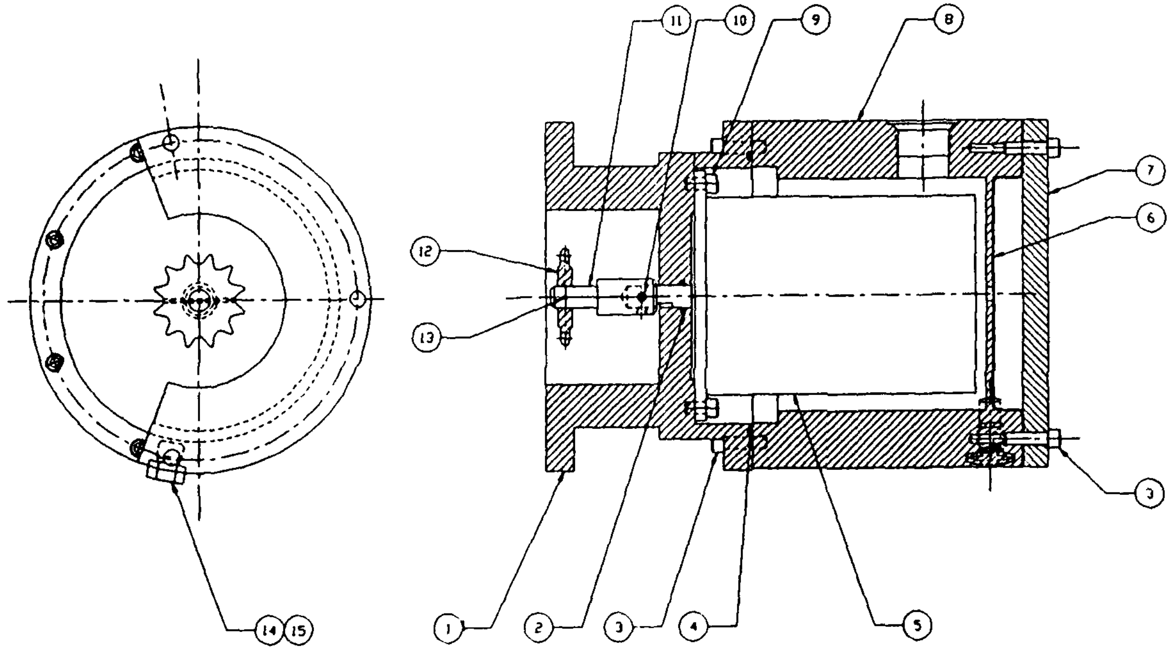

REVISIONS
Battelle
EXHAUST VALVE BODY
D 79986 744 AAR0051D
FULL
DELRIN ROD, 6.00 DIA.
SECTION AA
AAR0051D


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
0.372±0.001
.372
0.330
0.330
0.538
2.285
2.347
0.031
-A-
.002
3.409
1.31
0.75
.031 X 45°
A
A
82°
41°
ø.62
R1.218
R1.02
2 X R.50
-A-
.005
R.25
SECTION AA
ø0.376±0.001
-A-
.62
ø.136
THRU
ø.281
.50
.164-32UNC-2B
THRU
FIND NO
QTY
PART NO. OR IDENTIFYING NO.
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO
PER ASSY
NO. OF ASSYS
TOTAL
TO MAKE FINAL ASSEMBLY
TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx= ±.01
.xxx= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
316 STNL'S STL
SIGNATURE
DRAWN BY MWC
DRAFTING APPD
DESIGN APPD
APPD
APPD
PROJECT APPD
SPECIAL APPD
DIV 744
DATE 12/7/89
Battelle
Putting Technology to Work
TITLE
VALVE SPOOL
SIZE C
CODE IDENT. NO. 79986
DIV NO. 744
DWG NO. AAR0052C
REV.
SCALE FULL
ACCT
SHEET 1 OF 1
COMPUTER FILE AAR0052C


REVISIONS
8X ⌀.1470
↧ .88
V ⌀.22
.190-24UNC-2B
↧ .50
22.5° TYP.
45 TYP.
⌀.906
↧ THRU
.75-14 NPT
2.12
⌀4.41
⌀4.00
⌀5.97
R0.09
2.94
⌀3.50
2.91
0.44
2.62
2.74
4.50
0.50
0.75
1.63
"U"(.368) DRILL x 1.31 DP.
FORM & REAM FOR SAE-4
7/16-20 UNF-2B TAP x .44 DP.
SECTION AA
16X ⌀.1470
↧ .88
V ⌀.22
.190-24UNC-2B
↧ .50
1.38
1.00
⌀5.50
⌀.50 THRU
⌀1.25
R.12
1.06
1.75
1.63
2X ⌀.1470
↧ .88
V ⌀.22
.190-24UNC-2B
↧ .50
2X ⌀.0700
↧ THRU
V ⌀.094
.086-56UNC-2B
↧ THRU
0.25
0.63
1.50
3.00
⌀.25
↧ THRU
PARTS LIST
APPLICATION
DO NOT SCALE DRAWING
SIGNATURE
MWC
DATE
DELRIN ROD
6.00 DIA.
Battelle
EXHAUST VALVE
MOTOR BODY
D
79986
744
AAR0053D
FULL
1 OF 1
AAR0053D


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
0.062±0.005
ø 2.490±0.002
-A-
.002
0.31
.38
0.030 x 45°
BOTH SIDES
0.380±0.002
-A-
ø4.50
ø.218
THRU
ø.406
.19
FIND NO.
QTY
PART NO. OR IDENTIFYING NO.
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO.
PER ASSY
NO. OF ASSYS
TOTAL
TO MAKE FINAL ASSEMBLY
TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx= ±.01
.xxx= ±.005
ANGLES= ±1°
MATERIAL AND TREATMENT
DELRIN
SIGNATURE
DIV
DATE
DRAWN BY
MVC
744
12/14/89
DRAFTING APPD
DESIGN APPD
APPD.
APPD.
PROJECT APPD
SPECIAL APPD
Battelle
Putting Technology To Work
TITLE
VALVE COVER
SIZE
C
CODE IDENT. NO.
79986
DIV. NO.
744
DWG. NO.
AAR0054C
REV.
SCALE
FULL
ACCT
SHEET 1 OF 1
COMPUTER FILE AAR0054C


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
⌀.218 ↧ THRU
⌀5.50
⌀5.97
.44
.005
PARTS LIST
FIND NO. QTY PART NO. OR IDENTIFYING NO. DWG SIZE DESCRIPTION SPECIFICATION NOTE NO.
Battelle
Putting Technology To Work
TITLE
EXHAUST VALVE
MOTOR COVER
SIZE C CODE IDENT. NO. 79986 DIV NO 744 DWG NO AAR0055C REV.
SCALE FULL ACCT. SHEET 1 OF 1
SIGNATURE DIV DATE
DRAWN BY M. Simon 744
DRAFTING APPD
DESIGN APPD
APPD
PROJECT APPD
SPECIAL APPD
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE:
.XX= ±.01 .XXXX= -
.XXX= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
DELRIN ROD
6.00 DIA.
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO. PER ASSY NO. OF ASSYS TOTAL
TO MAKE FINAL ASSEMBLY TOTAL REQ'D
COMPUTER FILE AAR0055C



FIND NO.	QTY	PART NO. OR IDENTIFYING NO.	DWG SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.
15	1	3-904	-	"O" RING NITRILE(BUNA N)		
14	1	4P50N-SS	-	PLUG-STR. THD. 316 STNL'S STL		
13	1	1/16 x 100	-	ROLL PIN 316 STNL'S STL		
12	1		-	SPROCKET		
11	1	AAR0064B	B	AUX. SHAFT		
10	2	#8-32 x .25	-	SCREW, SOC. SET 316 STNL'S STL		
9	4	#10-24 x .50	-	SCREW, SHC 316 STNL'S STL		
8	1	AAR0060D	D	ROTARY VALVE MOTOR BODY		
7	1	AAR0055C	C	MOTOR BODY COVER		
6	1	H-400-100-DBJ	-	ROLLING DIAPHRAGM		
5	1	HM200-3450-350-AB	-	STEPPER MOTOR		
4	1	2-158	-	"O" RING NITRILE(BUNA N)		
3	8	#10-24 x .75	-	SCREW, SHC 316 STNL'S STL		
2	1	2-012	-	"O" RING NITRILE(BUNA N)		
1	1	AAR0056D	D	ROTARY VALVE MOTOR END CAP		

PARTS LIST

REVISIONS

APPLICATION

DO NOT SCALE DRAWING

SIGNATURE: MVC

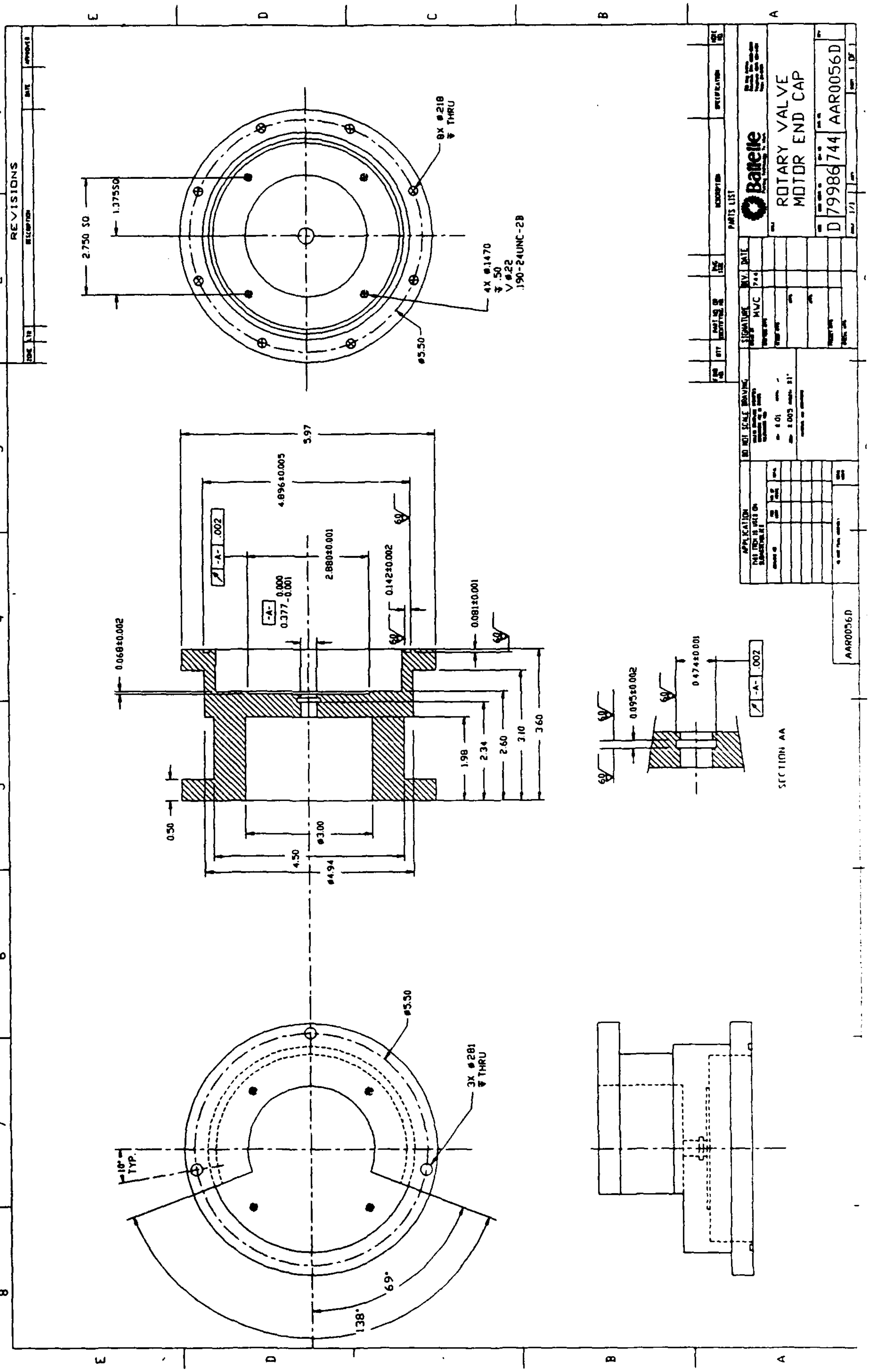
Battelle

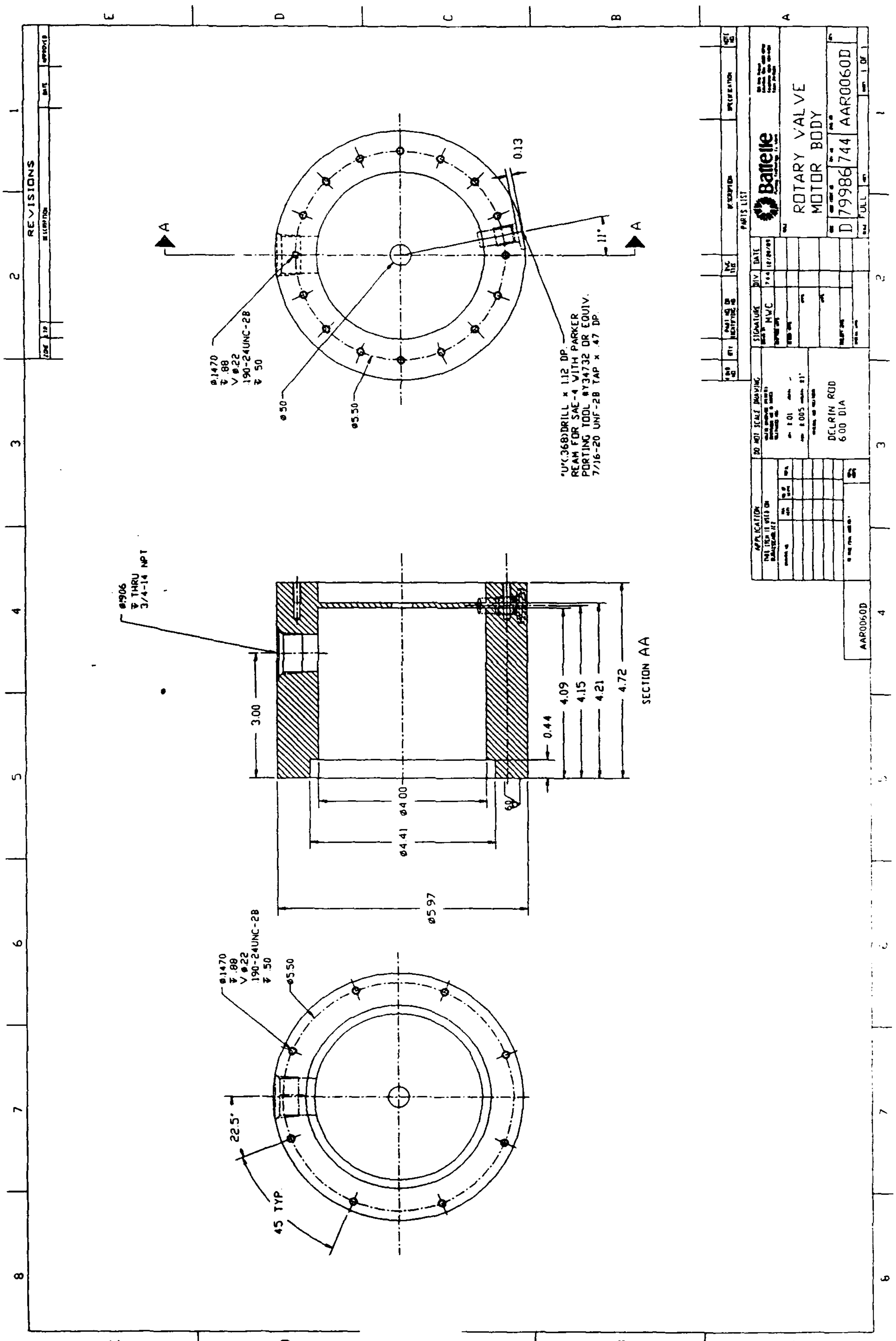
ROTARY VALVE MOTOR

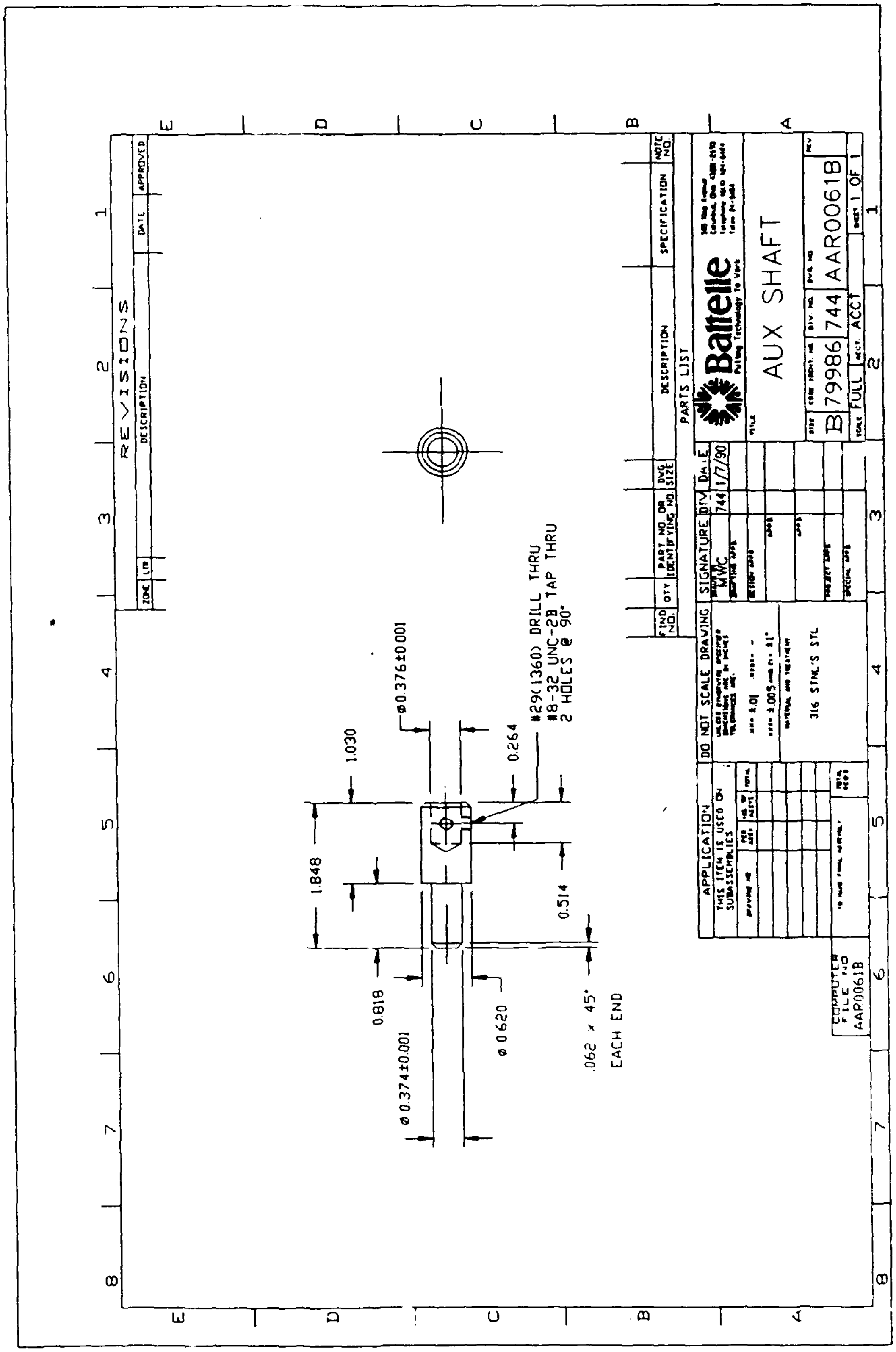
D 79986 744 AAR0057D

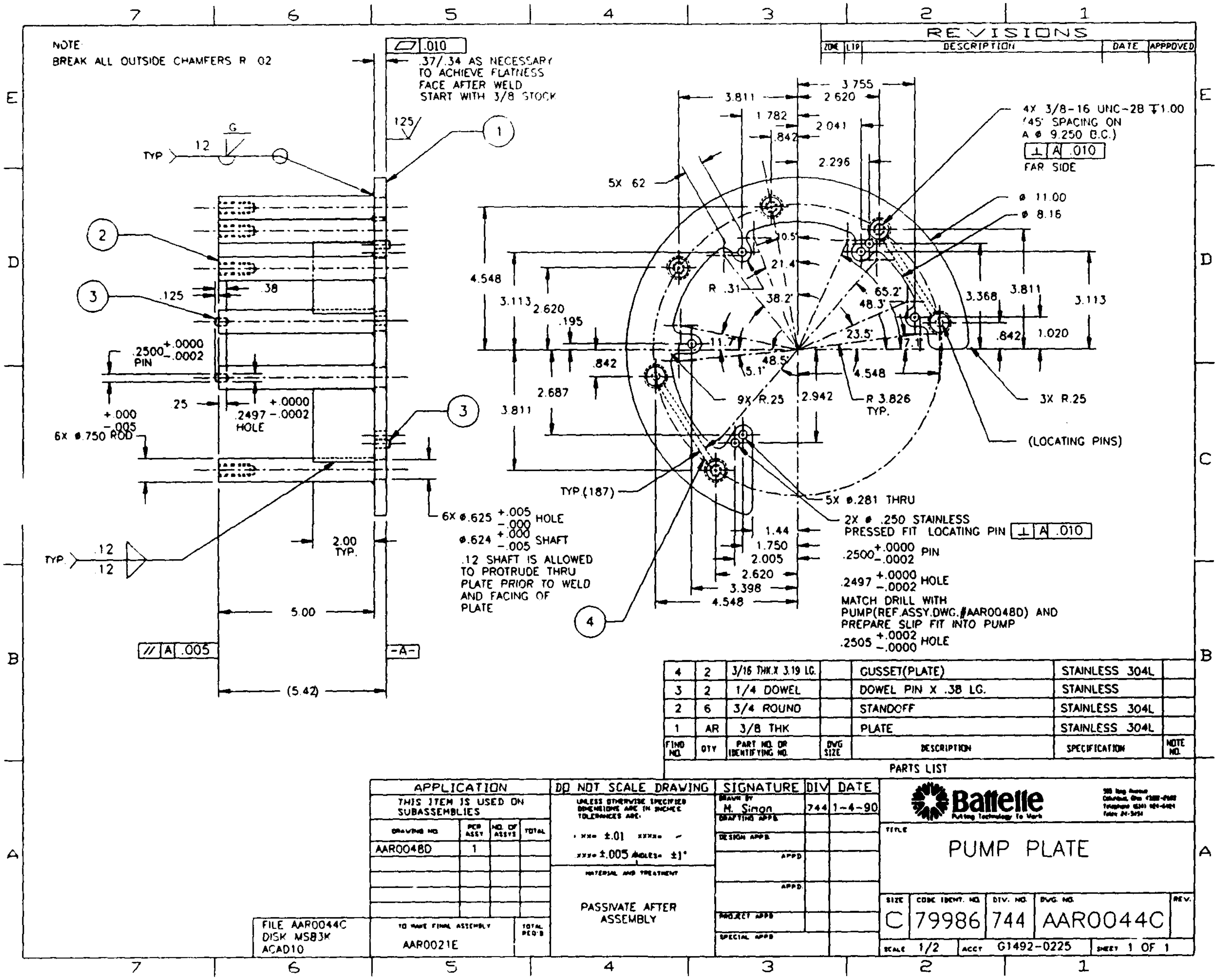
SHEET 1 OF 1

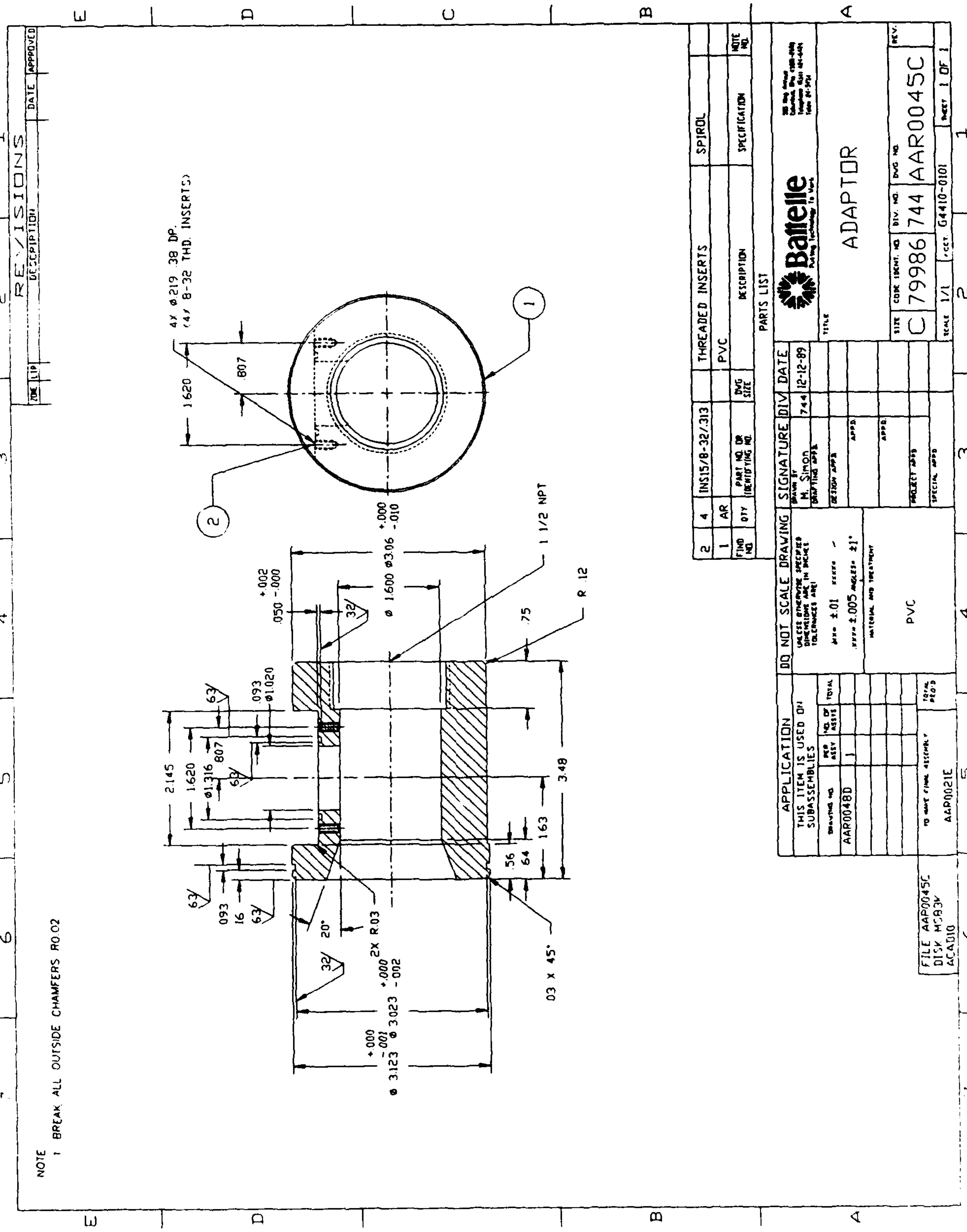
AAR0057D

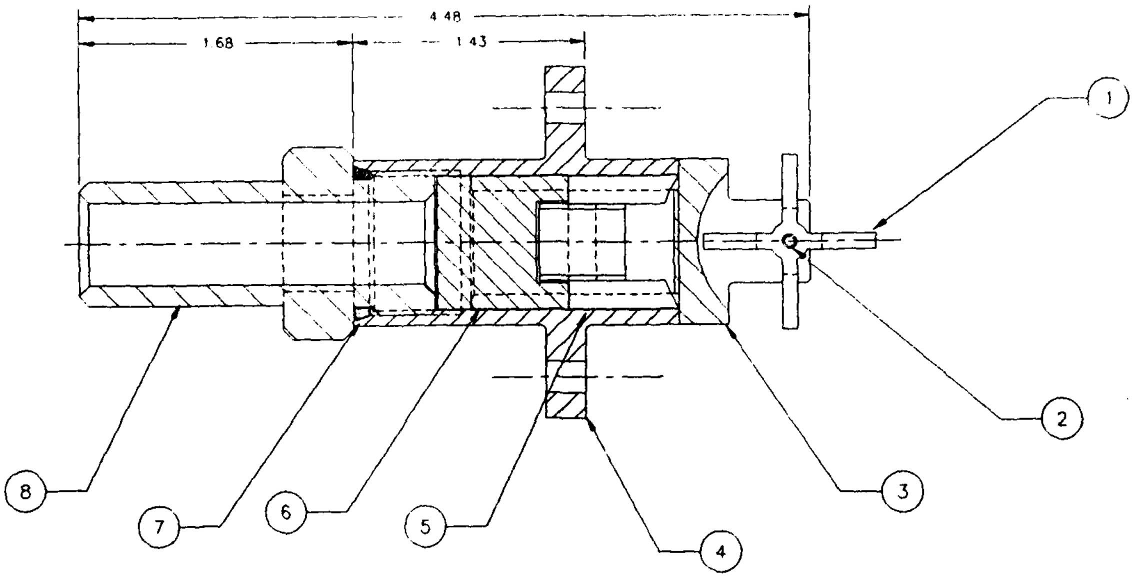

REVISIONS
ROTARY VALVE
MOTOR END CAP
Battelle
D 79986 744 AAR0056D
AAR0056D
PARTS LIST
DO NOT SCALE DRAWING
APPLICATION
8X ø.218 THRU
4X ø.1470 ▽ .50 V ø.22 .190-24UNC-2B
ø5.50
2.750 SQ
1.3755Q
5.97
4.896±0.005
2.880±0.001
0.142±0.002
0.081±0.001
0.068±0.002
0.377 -0.000/-0.001
-A-
.002
1.98
2.34
2.60
3.10
3.60
0.50
ø3.00
4.50
ø4.94
0.095±0.002
0.474±0.001
SECTION AA
ø5.30
3X ø.281 THRU
10° TYP.
69°
138°


REVISIONS
ROTARY VALVE
MOTOR BODY
Battelle
D 79986 744 AAR0060D
DELRIN ROD
6.00 DIA
SECTION AA
ø.1470
▽ .88
V ø.22
190-24UNC-2B
▽ .50
ø.50
ø5.50
0.13
11°
"U"(.368)DRILL x 1.12 DP.
REAM FOR SAE-4 WITH PARKER
PORTING TOOL #Y34732 OR EQUIV.
7/16-20 UNF-2B TAP x .47 DP.
ø.1906
▽ THRU
3/4-14 NPT
3.00
0.44
4.09
4.15
4.21
4.72
ø4.00
ø4.41
ø5.97
60°
22.5°
45 TYP.
AAR0060D


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
#29(1360) DRILL THRU
#8-32 UNC-2B TAP THRU
2 HOLES @ 90°
ø 0.376±0.001
1.030
0.264
1.848
0.514
0.818
ø 0.620
ø 0.374±0.001
.062 × 45°
EACH END
FIND NO.
QTY
PART NO. OR IDENTIFYING NO.
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
SIGNATURE
DIV
DATE
MWC
744
1/7/90
DO NOT SCALE DRAWING
316 STNL'S STL
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
Battelle
Putting Technology To Work
AUX SHAFT
B
79986
744
AAR0061B
FULL
ACCT
SHEET 1 OF 1
COMPUTER FILE NO
AAP0061B


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
NOTE:
BREAK ALL OUTSIDE CHAMFERS R .02
.37/.34 AS NECESSARY TO ACHIEVE FLATNESS FACE AFTER WELD START WITH 3/8 STOCK
4X 3/8-16 UNC-2B ↧1.00 45° SPACING ON A ø 9.250 B.C.)
FAR SIDE
ø 11.00
ø 8.16
5X 62
3X R.25
(LOCATING PINS)
9X R.25
R 3.826 TYP.
5X ø.281 THRU
2X ø .250 STAINLESS PRESSED FIT LOCATING PIN
.2497 +.0000 -.0002 HOLE
MATCH DRILL WITH PUMP(REF.ASSY.DWG.#AAR0048D) AND PREPARE SLIP FIT INTO PUMP
.2505 +.0002 -.0000 HOLE
6X ø.625 +.005 -.000 HOLE
ø.624 +.000 -.005 SHAFT
.12 SHAFT IS ALLOWED TO PROTRUDE THRU PLATE PRIOR TO WELD AND FACING OF PLATE
6X ø.750 ROD
TYP (.187)
2.00 TYP.
5.00
(5.42)
4 | 2 | 3/16 THK X 3.19 LG. | GUSSET(PLATE) | STAINLESS 304L
3 | 2 | 1/4 DOWEL | DOWEL PIN X .38 LG. | STAINLESS
2 | 6 | 3/4 ROUND | STANDOFF | STAINLESS 304L
1 | AR | 3/8 THK | PLATE | STAINLESS 304L
FIND NO. | QTY | PART NO. OR IDENTIFYING NO. | DWG SIZE | DESCRIPTION | SPECIFICATION | NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
AAR0048D 1
AAR0021E
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
.xx= ±.01
.xxx= ±.005 ANGLES= ±1°
PASSIVATE AFTER ASSEMBLY
SIGNATURE DIV DATE
H. Siman 744 1-4-90
Battelle
PUMP PLATE
SIZE C CODE IDENT. NO. 79986 DIV. NO. 744 DWG NO. AAR0044C
SCALE 1/2 ACCT G1492-0225 SHEET 1 OF 1
FILE AAR0044C
DISK MS83K
ACAD10


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
NOTE
1 BREAK ALL OUTSIDE CHAMFERS R0.02
4X ø.219 .38 DP.
(4) 8-32 THD. INSERTS)
1.620
.807
1 1/2 NPT
R .12
.75
3.48
1.63
.56
.64
2.145
1.620
ø1.316
.807
.093
ø1.020
.050 +.002 -.000
ø 1.600 ø3.06 +.000 -.010
ø 3.123 +.000 -.001 ø 3.023 +.000 -.002
2X R.03
20°
.03 X 45°
.093
.16
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
AAR0048D
AAP0021E
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.XX ±.01
.XXX ±.005 ANGLES ±1°
MATERIAL AND TREATMENT
PVC
SIGNATURE DIV DATE
DRAWN BY M. Simon 744 12-12-89
2 4 INS15/8-32/.313 THREADED INSERTS SPIROL
1 AR PVC
FIND NO. QTY PART NO. OR IDENTIFYING NO. DWG SIZE DESCRIPTION SPECIFICATION NOTE NO.
PARTS LIST
Battelle
ADAPTOR
SIZE C CODE IDENT. NO 79986 DIV. NO 744 DWG NO AAR0045C
SCALE 1/1 ACCT. G4410-0101 SHEET 1 OF 1
FILE AAP0045C
DISK MS83V
ACAU10



FIND NO.	QTY	PART NO. OR IDENTIFYING NO.	DWG SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.
8	1	AAR0067C	C	PLUG		
7	1			O-RING		
6	1	AAR0066C	C	RETAINER,COIL		
5	1			COIL		
4	1	AAR0065C	C	HOUSING		
3	1	AAR0064C	C	SHAFT MOUNT		
2	1			SHAFT		
1	1			PADDLE		

PARTS LIST

APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES

DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
AAR0048D	1		

TO MAKE FINAL ASSEMBLY: AAR0021E — TOTAL REQ'D

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.XXX± .XXXX±
.XX± ANGLES±
MATERIAL AND TREATMENT

SIGNATURE	DIV	DATE
DRAWN BY M. Simon	744	1-9-90
DRAFTING APPD		
DESIGN APPD		
APPD		
APPD		
PROJECT APPD		
SPECIAL APPD		

Battelle
Putting Technology To Work

TITLE
FLOWMETER ASSY.

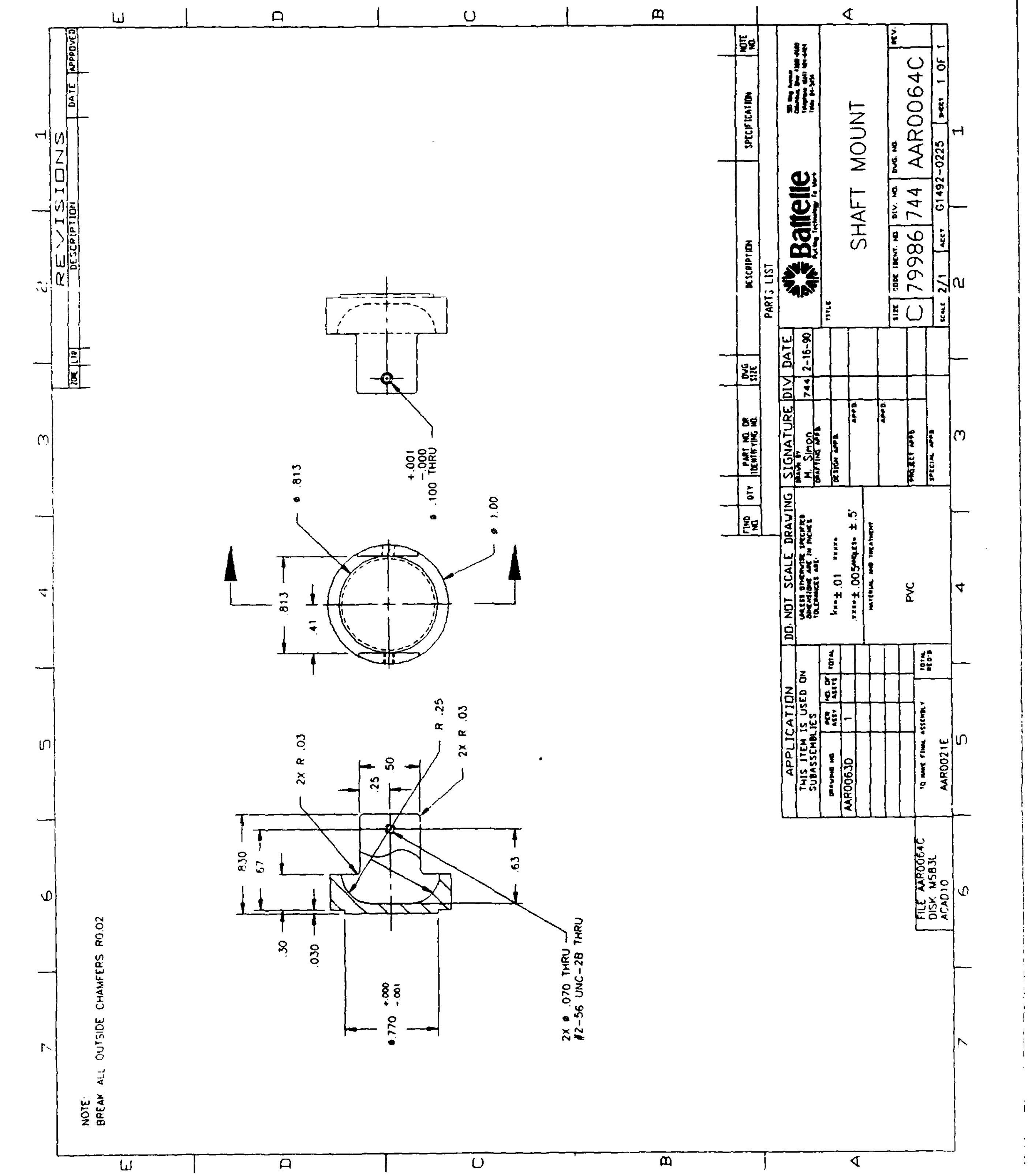
SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
C	79986	744	AAR0063C	

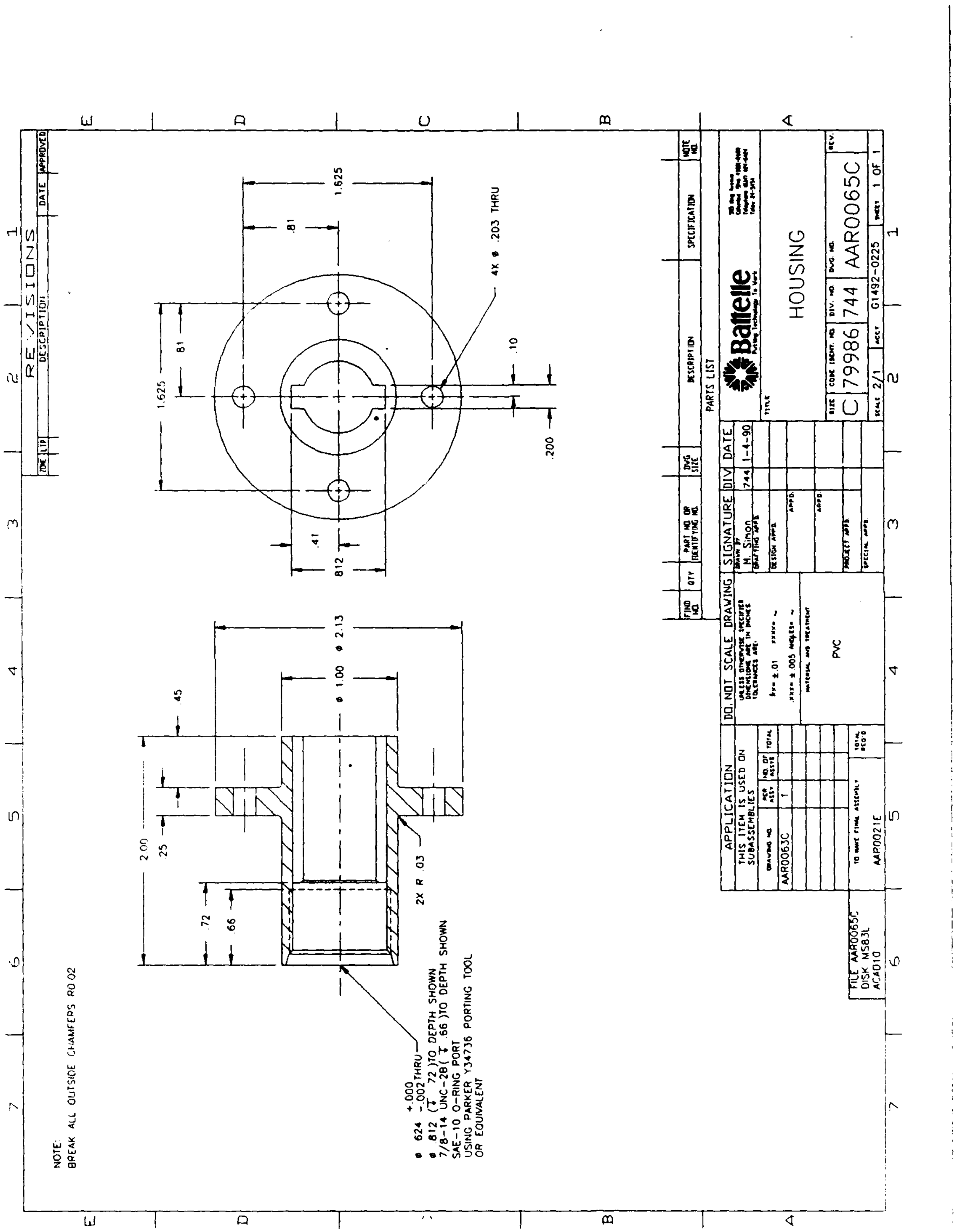
SCALE 2/1 ACCT G1492-0225 SHEET 1 OF 1

FILE AAR0063C
DISK MS83L
ACAD10

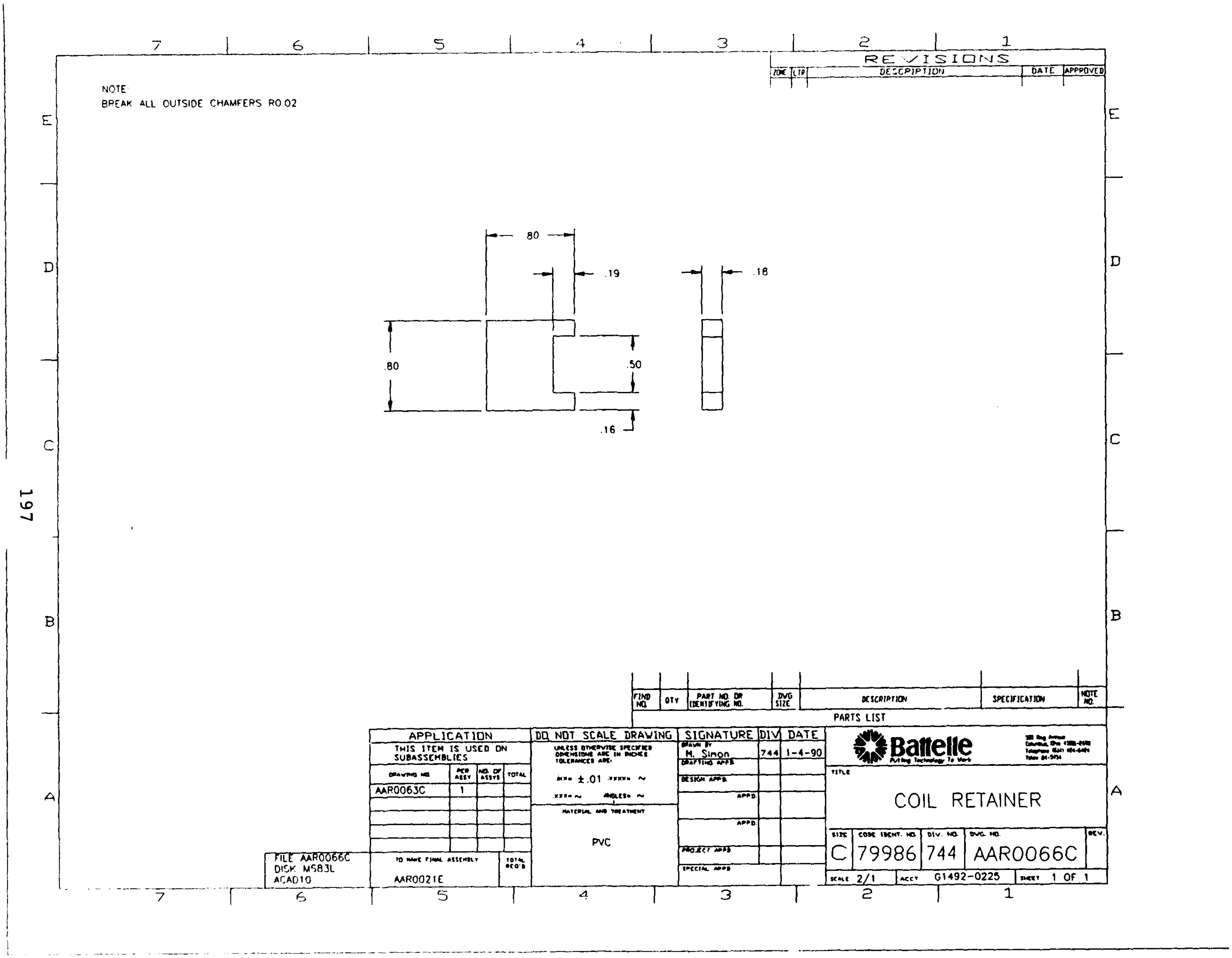
REVISIONS

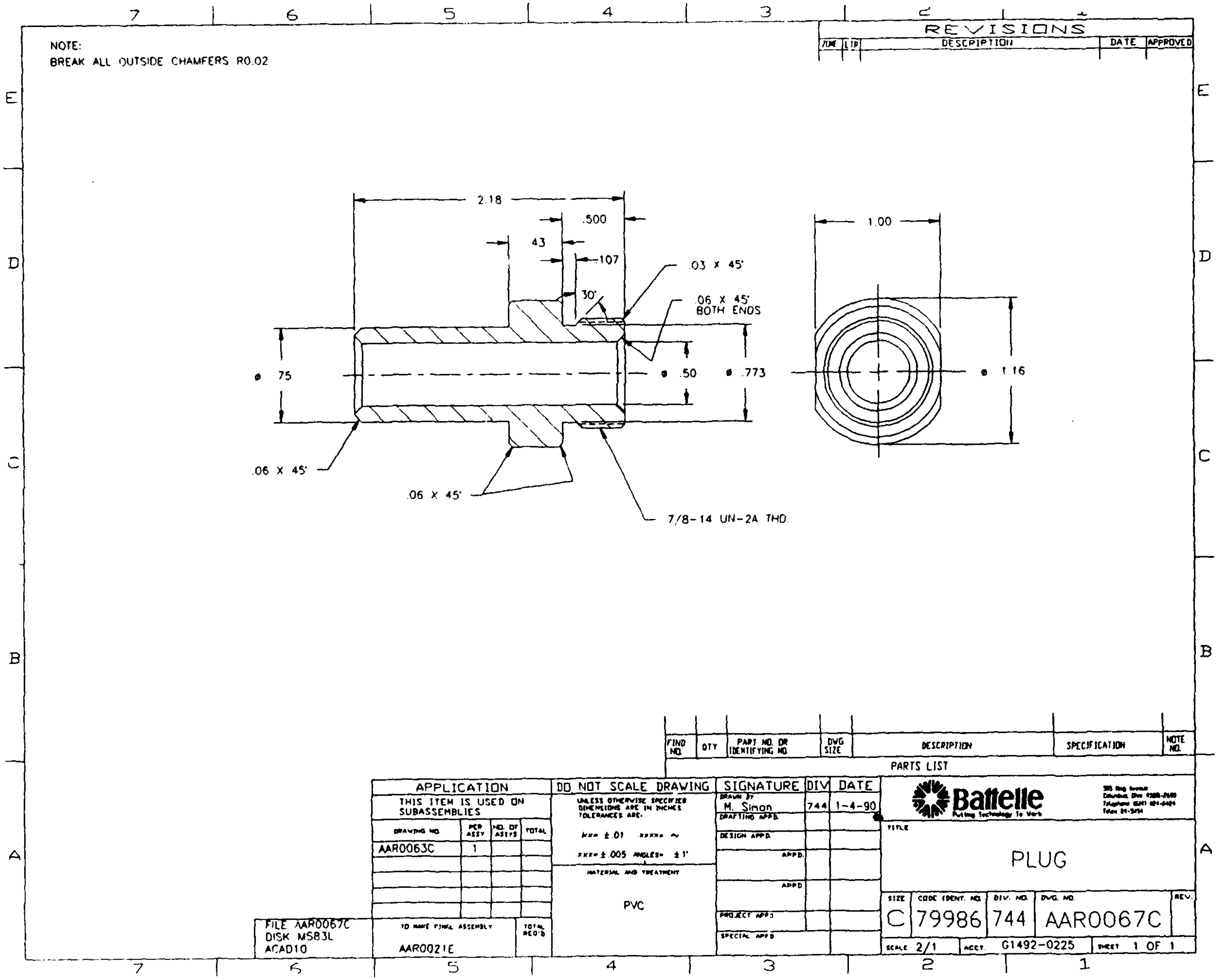
ZONE	LTR	DESCRIPTION	DATE	APPROVED

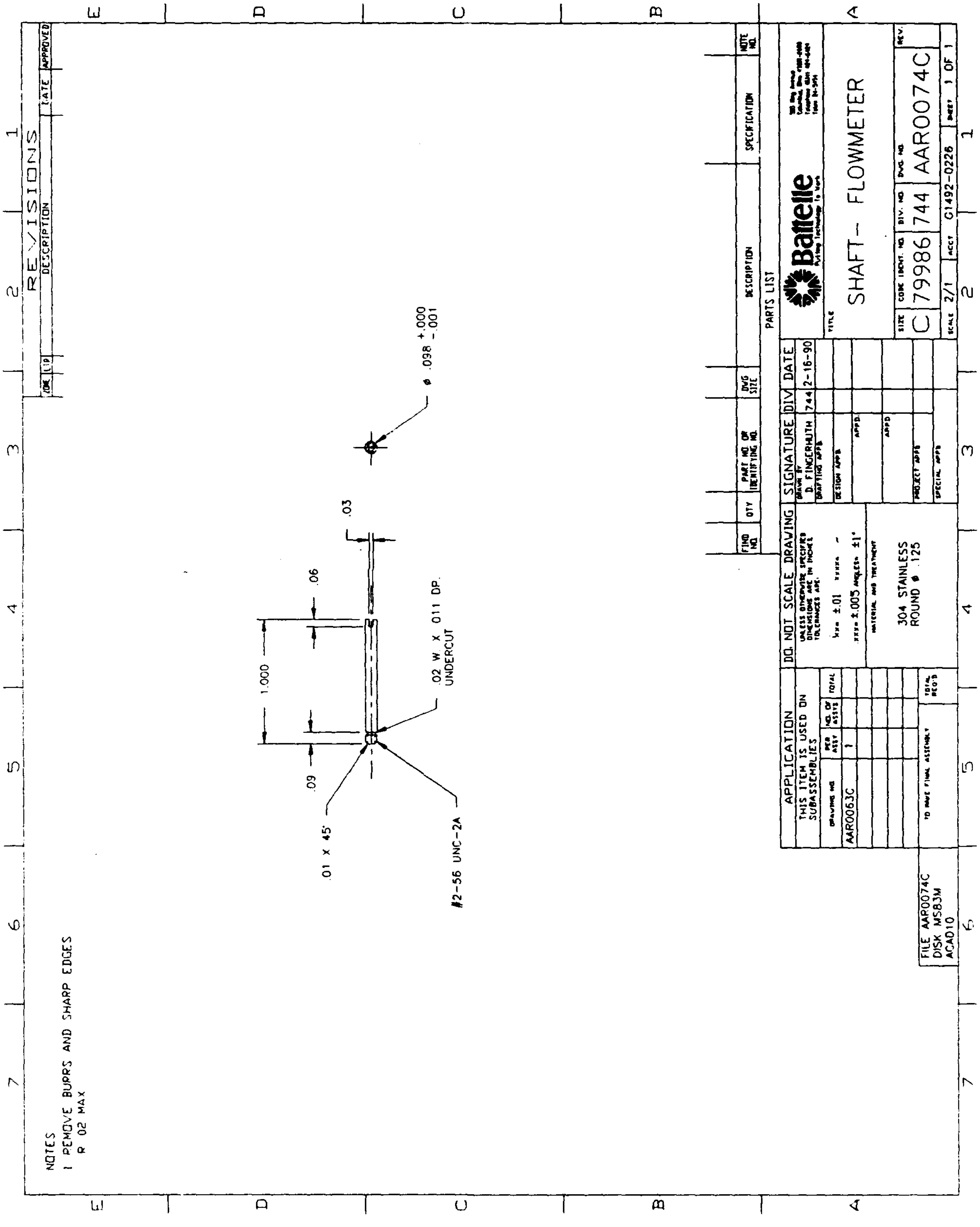

REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
NOTE:
BREAK ALL OUTSIDE CHAMFERS R0.02
2X R .03
R .25
2X R .03
.25
.50
.830
.67
.63
.30
.030
ø.770 +.000 -.001
2X ø .070 THRU
#2-56 UNC-2B THRU
ø .813
ø 1.00
.813
.41
ø .100 THRU +.001 -.000
FIND NO.
QTY
PART NO. OR IDENTIFYING NO.
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO.
PER ASSY
NO. OF ASSYS
TOTAL
AAR0063D
1
TO MAKE FINAL ASSEMBLY
TOTAL REQ'D
AAR0021E
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx ± .01
.xxx ± .005
ANGLES ± .5°
MATERIAL AND TREATMENT
PVC
SIGNATURE
DIV
DATE
DRAWN BY
H. Simon
744
2-16-90
DRAFTING APP'D
DESIGN APP'D
APP'D
PROJECT APP'D
SPECIAL APP'D
Battelle
Putting Technology To Work
TITLE
SHAFT MOUNT
SIZE
C
CODE IDENT. NO.
79986
DIV. NO.
744
DWG. NO.
AAR0064C
REV.
SCALE 2/1
ACCT G1492-0225
SHEET 1 OF 1
FILE AAR0064C
DISK MS83L
ACAD10
A
B
C
D
E
1
2
3
4
5
6
7



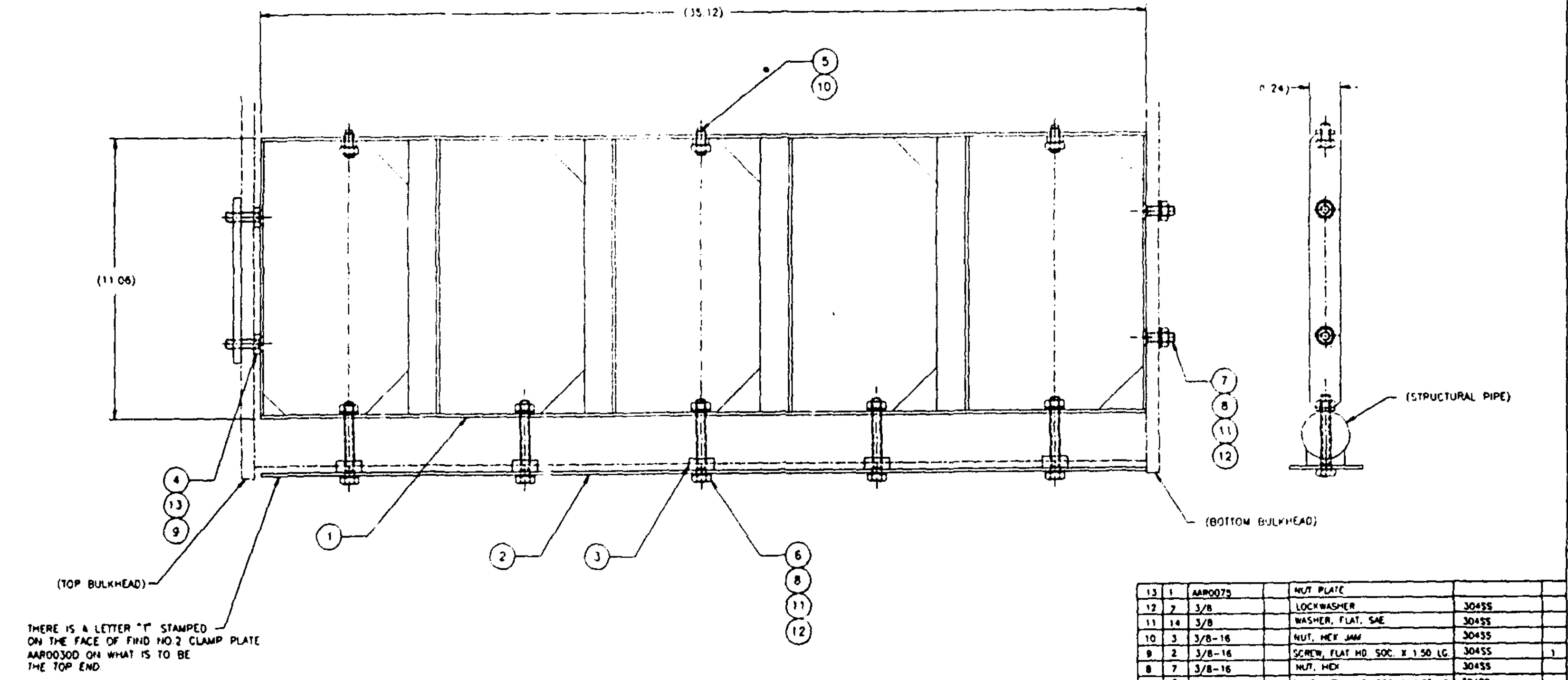
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
NOTE:
BREAK ALL OUTSIDE CHAMFERS R0.02
1.625
.81
4X ⌀ .203 THRU
.10
.200
.41
.812
⌀ 2.13
⌀ 1.00
.45
.25
2.00
.72
.66
2X R .03
⌀ .624 +.000 -.002 THRU
⌀ .812 (↧ .72) TO DEPTH SHOWN
7/8-14 UNC-2B (↧ .66) TO DEPTH SHOWN
SAE-10 O-RING PORT
USING PARKER Y34736 PORTING TOOL
OR EQUIVALENT
FIND NO.
QTY
PART NO. OR IDENTIFYING NO.
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
AAR0063C
1
TO MAKE FINAL ASSEMBLY
AAP0021E
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx ± .01
.xxx ± .005
MATERIAL AND TREATMENT
PVC
SIGNATURE
DIV
DATE
DRAWN BY
H. Simon
744
1-4-90
Battelle
HOUSING
SIZE
C
CODE IDENT. NO.
79986
DIV. NO.
744
DWG NO.
AAR0065C
REV.
SCALE 2/1
ACCT G1492-0225
SHEET 1 OF 1
FILE AAR0065C
DISK MS83L
ACAD10


NOTE:
BREAK ALL OUTSIDE CHAMFERS R0.02
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
80
.19
.18
.80
.50
.16
FIND NO. QTY PART NO. OR IDENTIFYING NO. DWG SIZE DESCRIPTION SPECIFICATION NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO. PER ASSY NO. OF ASSYS TOTAL
AAR0063C 1
TO MAKE FINAL ASSEMBLY
AAR0021E
TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
±.01
MATERIAL AND TREATMENT
PVC
SIGNATURE DIV DATE
DRAWN BY M. Simon 744 1-4-90
DRAFTING APPR
DESIGN APPR
APPD
APPD
PROJECT APPR
SPECIAL APPR
Battelle
Putting Technology To Work
TITLE
COIL RETAINER
SIZE C
CODE IDENT. NO. 79986
DIV. NO. 744
DWG. NO. AAR0066C
REV.
SCALE 2/1
ACCT G1492-0225
SHEET 1 OF 1
FILE AAR0066C
DISK MS83L
ACAD10


NOTE:
BREAK ALL OUTSIDE CHAMFERS R0.02
REVISIONS
DESCRIPTION
DATE
APPROVED
2.18
.500
43
.107
30°
.03 X 45°
.06 X 45° BOTH ENDS
⌀ 75
⌀ .50
⌀ .773
.06 X 45°
.06 X 45°
7/8-14 UN-2A THD.
1.00
⌀ 1.16
FIND NO.
QTY
PART NO. OR IDENTIFYING NO.
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO.
PER ASSY
NO. OF ASSYS
TOTAL
AAR0063C
1
TO MAKE FINAL ASSEMBLY
TOTAL REQ'D
AAR0021E
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.XX= ±.01
.XXX= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
PVC
SIGNATURE
DIV
DATE
DRAWN BY
M. Simon
744
1-4-90
DRAFTING APPD.
DESIGN APPD.
APPD.
APPD.
PROJECT APPD.
SPECIAL APPD.
Battelle
Putting Technology To Work
TITLE
PLUG
SIZE
C
CODE IDENT. NO.
79986
DIV. NO.
744
DWG. NO.
AAR0067C
REV.
SCALE 2/1
ACCT. G1492-0225
SHEET 1 OF 1
FILE AAR0067C
DISK MS83L
ACAD10


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
ø .098 +.000 -.001
.03
.06
1.000
.02 W. x .011 DP. UNDERCUT
.09
.01 x 45°
#2-56 UNC-2A
NOTES
1 REMOVE BURRS AND SHARP EDGES R .02 MAX
FIND NO.
QTY
PART NO OR IDENTIFYING NO.
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO.
PER ASSY
NO. OF ASSYS
TOTAL
AAR0063C
1
TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx= ±.01
.xxx= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
304 STAINLESS ROUND ø .125
SIGNATURE
DIV
DATE
DRAWN BY D. FINGERHUTH
744
2-16-90
DRAFTING APPR
DESIGN APPR
APPD
PROJECT APPR
SPECIAL APPR
Battelle
Putting Technology to Work
TITLE
SHAFT- FLOWMETER
SIZE
C
CODE IDENT. NO
79986
DIV. NO
744
DWG. NO
AAR0074C
REV.
SCALE 2/1
ACCT G1492-0226
SHEET 1 OF 1
FILE AAR0074C
DISK MSB3M
ACAD10

NOTE
1. INSTALL ALL FASTENERS TO FINGER TIGHT. TIGHTEN FIND NO. 7 FIRST, FIND NO. 9 SECOND, FIND NO. 8 LAST



FIND NO	QTY	PART NO OR IDENTIFYING NO	DWG SIZE	DESCRIPTION	SPECIFICATION	NOTE NO
13	1	AAR0075		NUT PLATE		
12	2	3/8		LOCKWASHER	304SS	
11	14	3/8		WASHER, FLAT, SAE	304SS	
10	3	3/8-16		NUT, HEX JAM	304SS	
9	2	3/8-16		SCREW, FLAT HD. SOC. X 1.50 LG.	304SS	1
8	7	3/8-16		NUT, HEX	304SS	
7	2	3/8-16		SCREW, FLAT HD. SOC. X 1.25 LG.	304SS	1
6	5	3/8-16		SCREW, HEX HD. X 3.00 LG.	304SS	1
5	3	AAR0088B	B	SETSCREW		
4	2	AAR0076		SPACER		
3	5	AAR0031B	B	CHOCK, SPACER		
2	1	AAR00300	D	CLAMP PLATE		
1	1	AAR0034D	D	LADDER		

PARTS LIST

APPLICATION
AAR0021E B

DO NOT SCALE DRAWING

SIGNATURE: M. Simon | 744 | 2-27-90

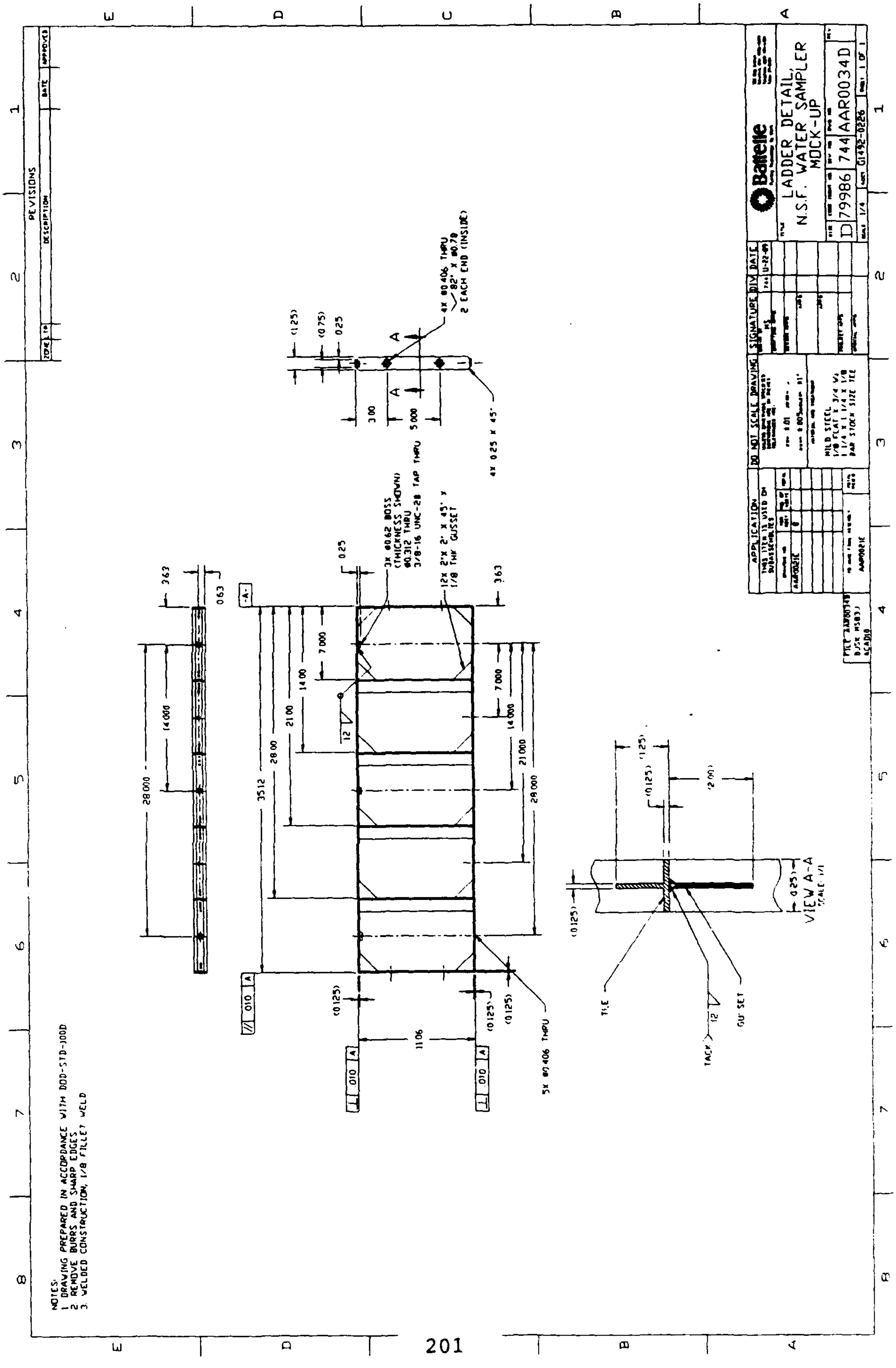
Battelle

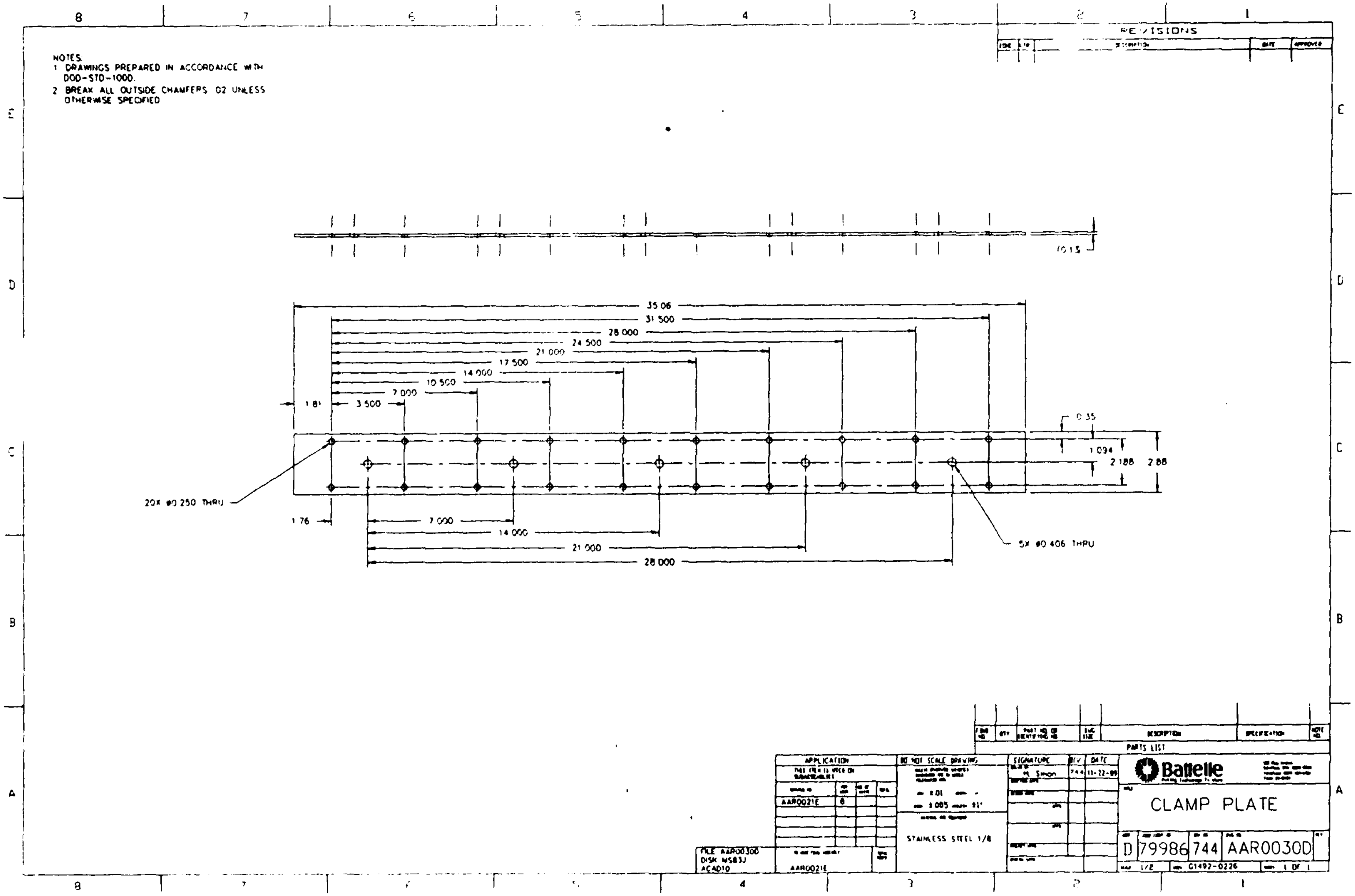
LADDER ASSEMBLY

D 79986 744 AAR0071D

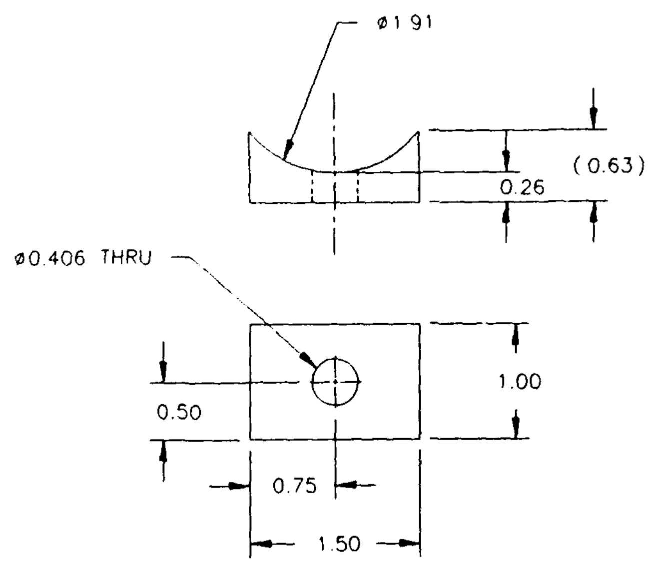
1/2 G1492-0226 1 OF 1

FILE AAR0071D
DISK MS83L
ACAD10


LADDER DETAIL,
N.S.F. WATER SAMPLER
MOCK-UP
Battelle
D 79986 744 AAR0034D
NOTES:
1 DRAWING PREPARED IN ACCORDANCE WITH DOD-STD-100D
2 REMOVE BURRS AND SHARP EDGES
3 WELDED CONSTRUCTION, 1/8 FILLET WELD
REVISIONS
DESCRIPTION
DATE
APPROVED
APPLICATION
DO NOT SCALE DRAWING
SIGNATURE
DIV
DATE
MILD STEEL
1/8 FLAT X 3/4 W
1 1/4 X 1 1/4 X 1/8
BAR STOCK SIZE TEE
3X Ø.062 BOSS
(THICKNESS SHOWN)
Ø0.312 THRU
3/8-16 UNC-2B TAP THRU
12X 2"X 2" X 45° X
1/8 THK GUSSET
4X Ø0.406 THRU
82° X Ø0.78
2 EACH END (INSIDE)
4X 0.25 X 45°
5X Ø0.406 THRU
VIEW A-A
SCALE 1/1
TIE
TACK
GUSSET
28.000
14.000
35.12
28.00
21.00
14.00
7.000
21.000
11.06
.363
.063
.025
.010
5.000
3.00


NOTES
1 DRAWINGS PREPARED IN ACCORDANCE WITH DOD-STD-1000.
2 BREAK ALL OUTSIDE CHAMFERS .02 UNLESS OTHERWISE SPECIFIED
REVISIONS
35.06
31.500
28.000
24.500
21.000
17.500
14.000
10.500
7.000
3.500
1.81
1.76
20X ⌀0.250 THRU
5X ⌀0.406 THRU
0.35
1.094
2.188
2.88
7.000
14.000
21.000
28.000
PARTS LIST
APPLICATION
DO NOT SCALE DRAWING
SIGNATURE
M. Simon
11-22-89
Battelle
CLAMP PLATE
D
79986
744
AAR0030D
1/2
G1492-0226
1 OF 1
AAR0021E
STAINLESS STEEL 1/8
FILE AAR0030D
DISK MSB3J
ACAD10

NOTES:
1 DRAWINGS PREPARED IN ACCORDANCE WITH DOD-STD-1000.
2 BREAK ALL OUTSIDE CHAMFERS .02 UNLESS OTHERWISE SPECIFIED.



REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIND NO	QTY	PART NO. OR IDENTIFYING NO.	DWG SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.

PARTS LIST

APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES

DRAWING NO	PER ASSY	NO. OF ASSYS	TOTAL

TO MAKE FINAL ASSEMBLY — TOTAL REQ'D

FILE AAR0031B
DISK MS83J
ACAD10

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
xx= ±.01 xxxx= ~
xxx= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
MILD STEEL

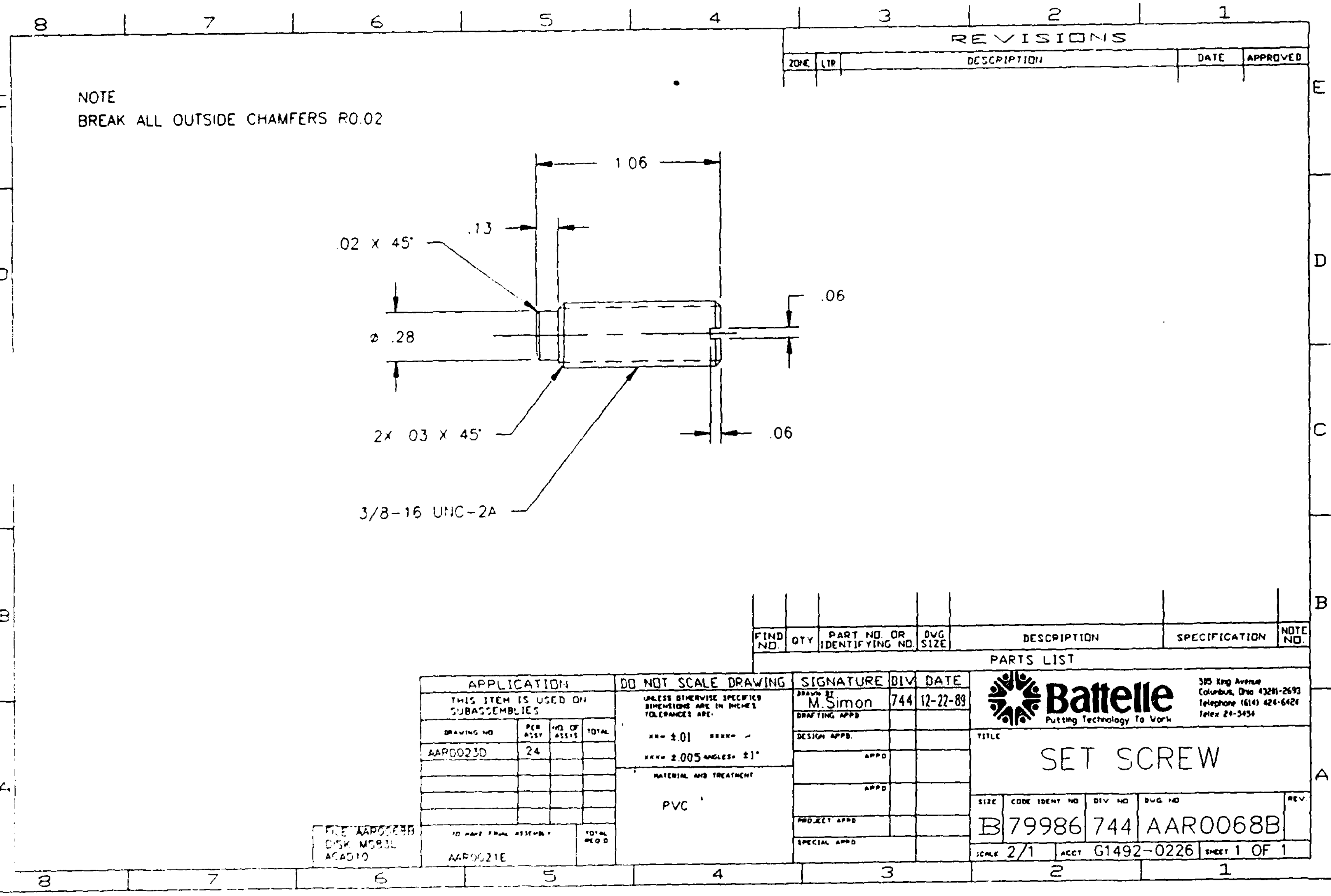
SIGNATURE	DIV	DATE
DRAWN BY M. Simon	744	11-15-89
DRAFTING APPD.		
DESIGN APPD.		
APPD		
APPD		
PROJECT APPD		
SPECIAL APPD		

Battelle
Putting Technology To Work
505 King Avenue
Columbus, Ohio 43201-2693
Telephone (614) 424-6424
Telex 24-5454

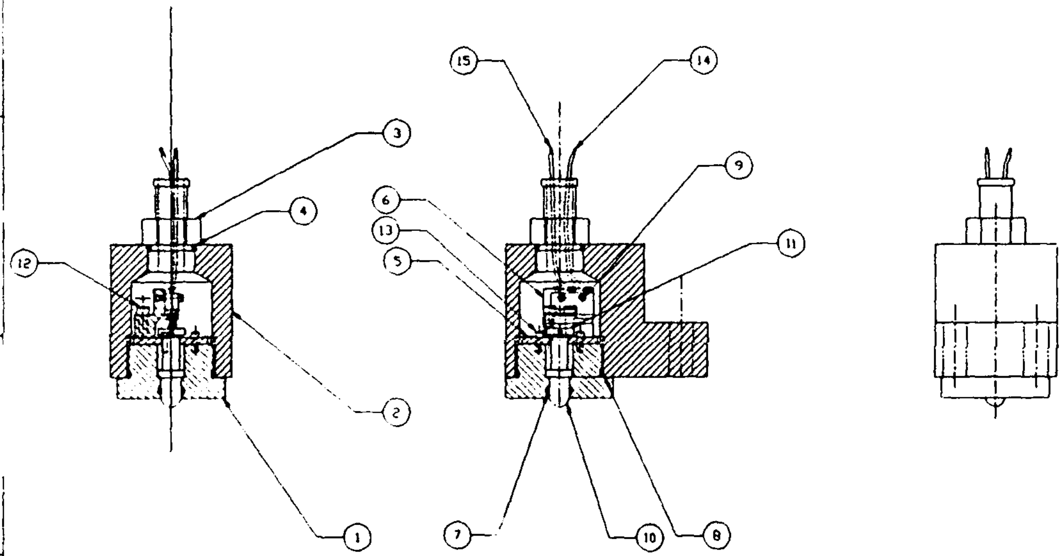
TITLE
CHOCK, CLAMP PLATE

SIZE	CODE IDENT NO	DIV NO	DWG NO	REV
B	79986	744	AAR0031B	

SCALE 1/1 ACCT G1492-0226 SHEET 1 OF 1



NOTE
BREAK ALL OUTSIDE CHAMFERS R0.02
1.06
.13
.02 X 45°
.06
⌀ .28
2X .03 X 45°
.06
3/8-16 UNC-2A
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
FIND NO. QTY PART NO. OR IDENTIFYING NO. DWG SIZE DESCRIPTION SPECIFICATION NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO PER ASSY NO. OF ASSYS TOTAL
AAR0023D 24
AAR0021E
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.XX= ±.01
.XXX= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
PVC
SIGNATURE DIV DATE
DRAWN BY M.Simon 744 12-22-89
DRAFTING APPD
DESIGN APPD.
APPD
APPD
PROJECT APPD
SPECIAL APPD
Battelle
Putting Technology To Work
505 King Avenue
Columbus, Ohio 43201-2693
Telephone (614) 424-6424
Telex 24-5454
TITLE
SET SCREW
SIZE CODE IDENT NO DIV NO DWG NO REV
B 79986 744 AAR0068B
SCALE 2/1 ACCT G1492-0226 SHEET 1 OF 1



REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIND NO.	QTY	PART NO. OR IDENTIFYING NO.	DWG SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.
15	12'	83026-9	-	WIRE, WHITE 22AWG	BELDEN OR EQUIV.	
14	12'	83026-5	-	WIRE, GREEN, 22AWG	BELDEN OR EQUIV.	
13	3	#6-32 x .25	-	SCREW, SHC 316 STNL'S STL		
12	2	#6-32 x .75	-	SCREW, SHC 316 STNL'S STL		
11	1	AAR0077B	B	ROTARY SWITCH ADJUSTING SCREW		
10	1	AAR0074B	B	ROTARY VALVE SWITCH PLUNGER		
9	2	#2-56 x .50	-	SCREW, SHC 316 STNL'S STL		
8	1	3-920	-	"O" RING NITRILE(BUNA N)		
7	1	2-012	-	"O" RING NITRILE(BUNA N)		
6	1	AAR0075C	C	ROTARY VALVE SWITCH MOUNT		
5	1	AAR0057B	B	ROTARY VALVE SWITCH SPRING RETAINER		
4	1	3-910	-	"O" RING NITRILE(BUNA N)		
3	1	AAR0076B	B	ROTARY VALVE SWITCH FITTING		
2	1	AAR0070C	C	ROTARY VALVE SWITCH BODY		
1	1	AAR0073C	C	ROTARY VALVE PLUG		

PARTS LIST

APPLICATION

DO NOT SCALE DRAWING

± .01 ± .005 ±1°

SIGNATURE: HVC | REV: 744 | DATE: 1/15/90

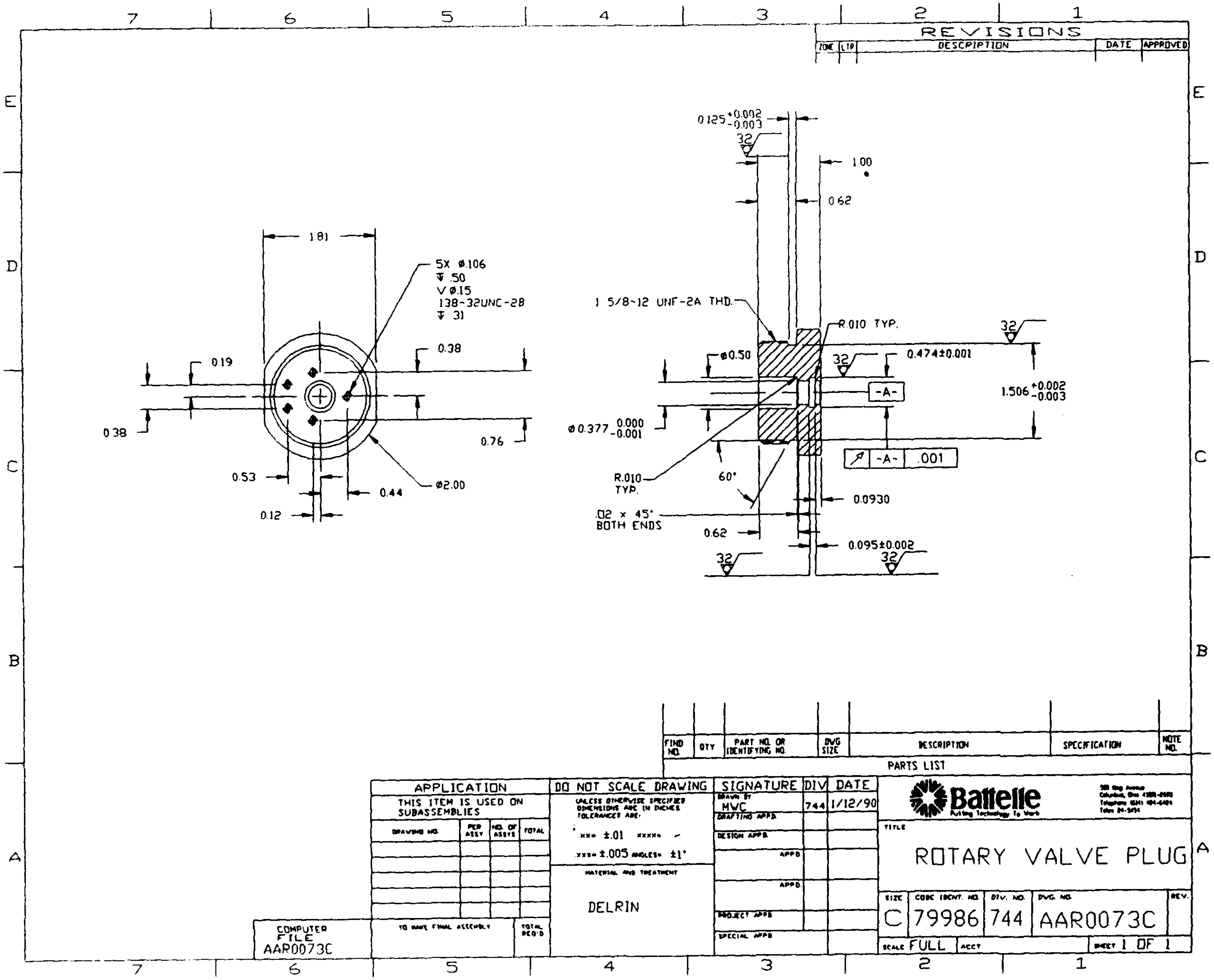
Battelle

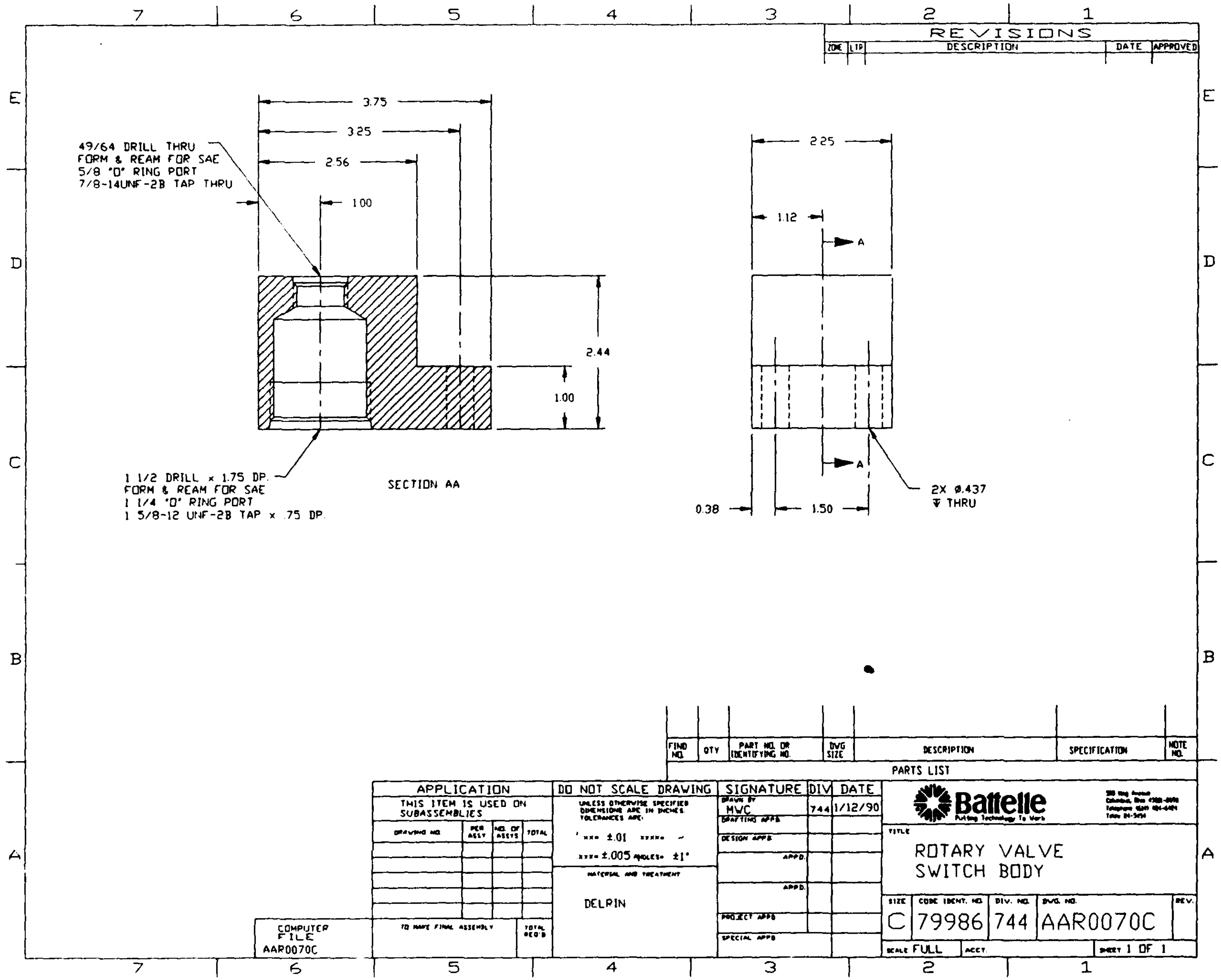
HOME POSITION SWITCH ASS'Y

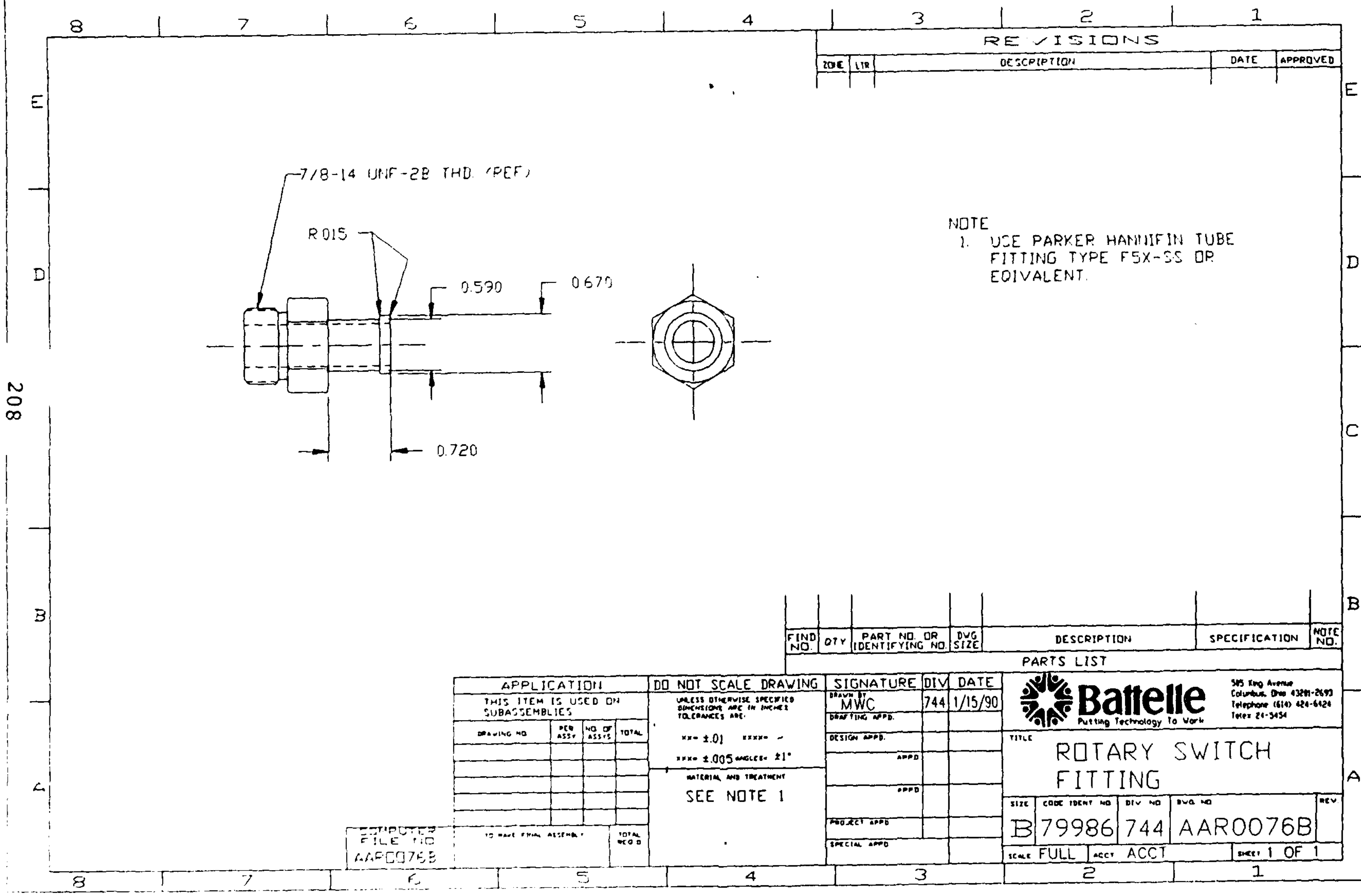
D | 79986 | 744 | AAR0078D

SCALE FULL | SHEET 1 OF 1

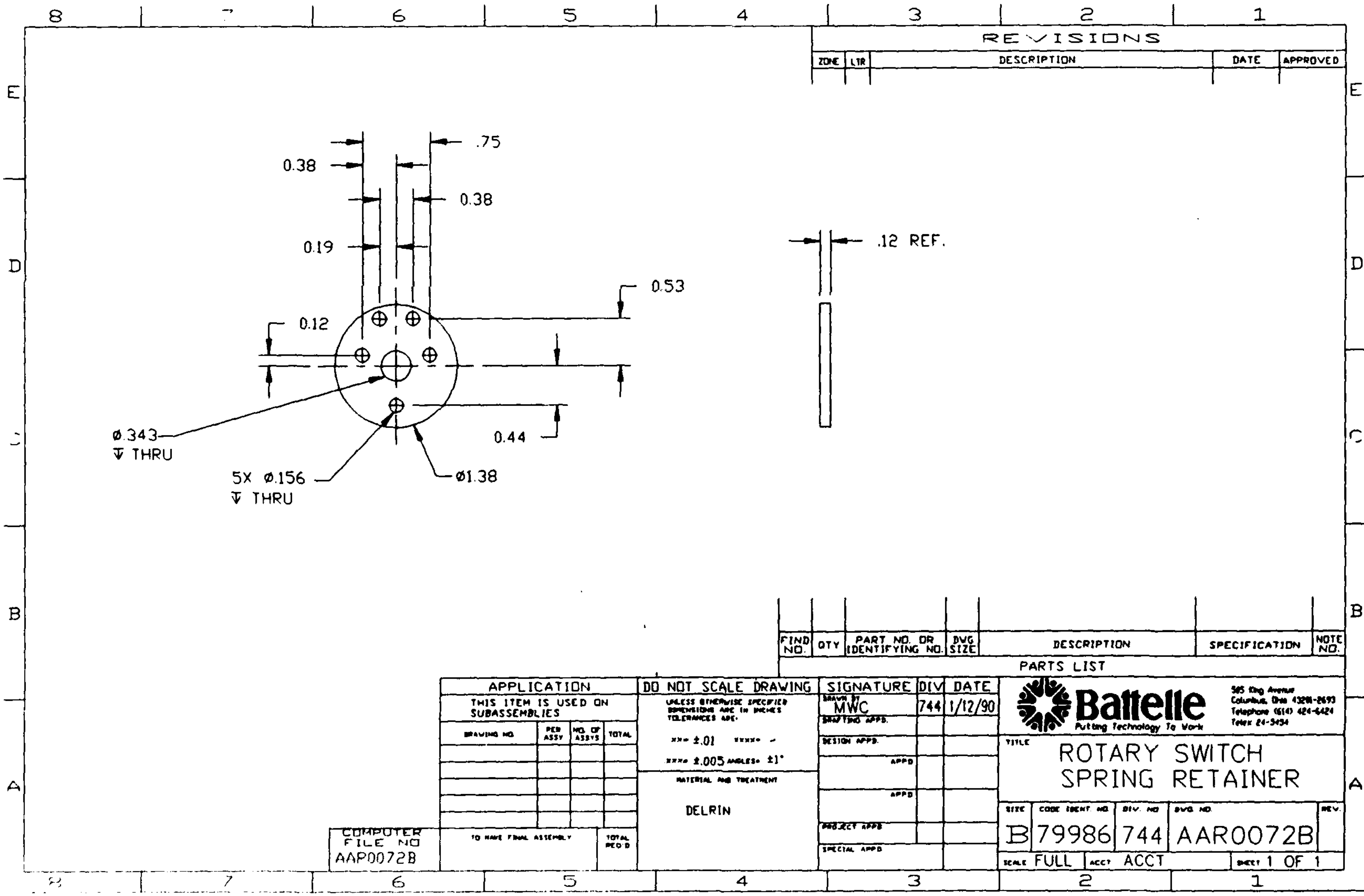
COMPUTER FILE NO. AAR0078D


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
5X Ø.106
↧ .50
V Ø.15
138-32UNC-2B
↧ .31
1.81
0.19
0.38
0.38
0.76
0.53
0.44
0.12
Ø2.00
0.125 +0.002 -0.003
1.00
0.62
1 5/8-12 UNF-2A THD.
R.010 TYP.
Ø0.50
0.474±0.001
-A-
1.506 +0.002 -0.003
Ø0.377 0.000 -0.001
.001
R.010 TYP.
60°
.02 x 45° BOTH ENDS
0.0930
0.62
0.095±0.002
32
FIND NO. | QTY | PART NO. OR IDENTIFYING NO. | DWG SIZE | DESCRIPTION | SPECIFICATION | NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO. | PER ASSY | NO. OF ASSYS | TOTAL
TO MAKE FINAL ASSEMBLY | TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx= ±.01
.xxx= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
DELRIN
SIGNATURE | DIV | DATE
DRAWN BY MVC | 744 | 1/12/90
DRAFTING APPR
DESIGN APPR
APPD
APPD
PROJECT APPR
SPECIAL APPR
Battelle
Putting Technology To Work
TITLE
ROTARY VALVE PLUG
SIZE C | CODE IDENT. NO. 79986 | DIV. NO. 744 | DWG. NO. AAR0073C | REV.
SCALE FULL | ACCT | SHEET 1 OF 1
COMPUTER FILE AAR0073C

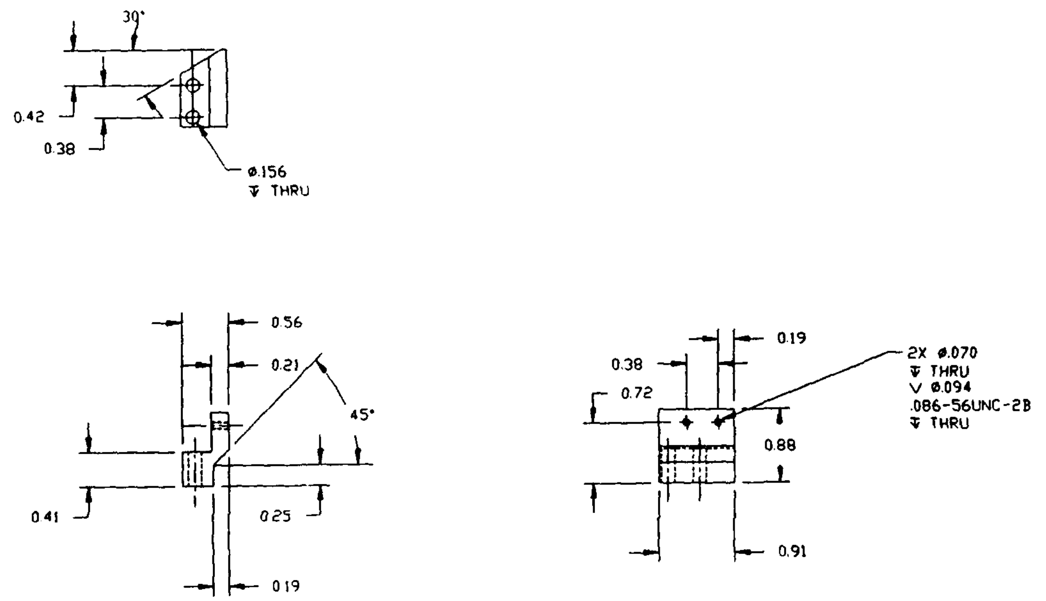

REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
3.75
3.25
2.56
1.00
49/64 DRILL THRU
FORM & REAM FOR SAE
5/8 "O" RING PORT
7/8-14UNF-2B TAP THRU
2.44
1.00
1 1/2 DRILL x 1.75 DP.
FORM & REAM FOR SAE
1 1/4 "O" RING PORT
1 5/8-12 UNF-2B TAP x .75 DP.
SECTION AA
2.25
1.12
A
A
0.38
1.50
2X Ø.437
THRU
FIND NO. | QTY | PART NO. OR IDENTIFYING NO. | DWG SIZE | DESCRIPTION | SPECIFICATION | NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO. | PER ASSY | NO. OF ASSYS | TOTAL
TO MAKE FINAL ASSEMBLY | TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx= ±.01
.xxx= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
DELRIN
SIGNATURE | DIV | DATE
DRAWN BY MWC | 744 | 1/12/90
DRAFTING APPR
DESIGN APPR
APPD.
APPD.
PROJECT APPR
SPECIAL APPR
Battelle
Putting Technology To Work
TITLE
ROTARY VALVE
SWITCH BODY
SIZE C | CODE IDENT. NO. 79986 | DIV. NO. 744 | DWG. NO. AAR0070C | REV.
SCALE FULL | ACCT. | SHEET 1 OF 1
COMPUTER FILE
AAR0070C



REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
7/8-14 UNF-2B THD. (REF)
R.015
0.590
0.670
0.720
NOTE
1. USE PARKER HANNIFIN TUBE FITTING TYPE F5X-SS OR EQIVALENT.
FIND NO. QTY PART NO. OR IDENTIFYING NO. DWG SIZE DESCRIPTION SPECIFICATION NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO PER ASSY NO OF ASSYS TOTAL
TO MAKE FINAL ASSEMBLY TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.XX= ±.01
.XXX= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
SEE NOTE 1
SIGNATURE DIV DATE
DRAWN BY MWC 744 1/15/90
DRAFTING APPD.
DESIGN APPD.
APPD
APPD
PROJECT APPD
SPECIAL APPD
Battelle
Putting Technology To Work
505 King Avenue
Columbus, Ohio 43201-2693
Telephone (614) 424-6424
Telex 24-5454
TITLE
ROTARY SWITCH FITTING
SIZE CODE IDENT NO DIV NO DWG NO REV
B 79986 744 AAR0076B
SCALE FULL ACCT ACCT SHEET 1 OF 1
COMPUTER FILE NO
AAR0076B



REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
.75
0.38
0.38
0.19
0.12
0.53
0.44
.12 REF.
ø.343
THRU
5X ø.156
THRU
ø1.38
FIND NO.
QTY
PART NO. OR IDENTIFYING NO.
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO
PER ASSY
NO. OF ASSYS
TOTAL
TO HAVE FINAL ASSEMBLY
TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xx= ±.01
.xxx= ±.005 ANGLES= ±1°
MATERIAL AND TREATMENT
DELRIN
SIGNATURE
DIV
DATE
DRAWN BY
MWC
744
1/12/90
DRAFTING APPD.
DESIGN APPD.
APPD
APPD
PROJECT APPD
SPECIAL APPD
Battelle
Putting Technology To Work
505 King Avenue
Columbus, Ohio 43201-2693
Telephone (614) 424-6424
Telex 24-5454
TITLE
ROTARY SWITCH
SPRING RETAINER
SIZE
CODE IDENT NO
DIV NO
DWG NO
REV
B
79986
744
AAR0072B
SCALE FULL
ACCT ACCT
SHEET 1 OF 1
COMPUTER FILE NO
AAP0072B



REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIND NO.	QTY	PART NO. OR IDENTIFYING NO.	DWG SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.

PARTS LIST

APPLICATION

THIS ITEM IS USED ON SUBASSEMBLIES

DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL

TO MAKE FINAL ASSEMBLY — TOTAL REQ'D

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:

.XX= ±.01 .XXXX= ~

.XXX= ±.005 ANGLES= ±1°

MATERIAL AND TREATMENT

DELRIN

SIGNATURE	DIV	DATE
DRAWN BY MWC	744	1/15/90
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

Battelle
Putting Technology To Work

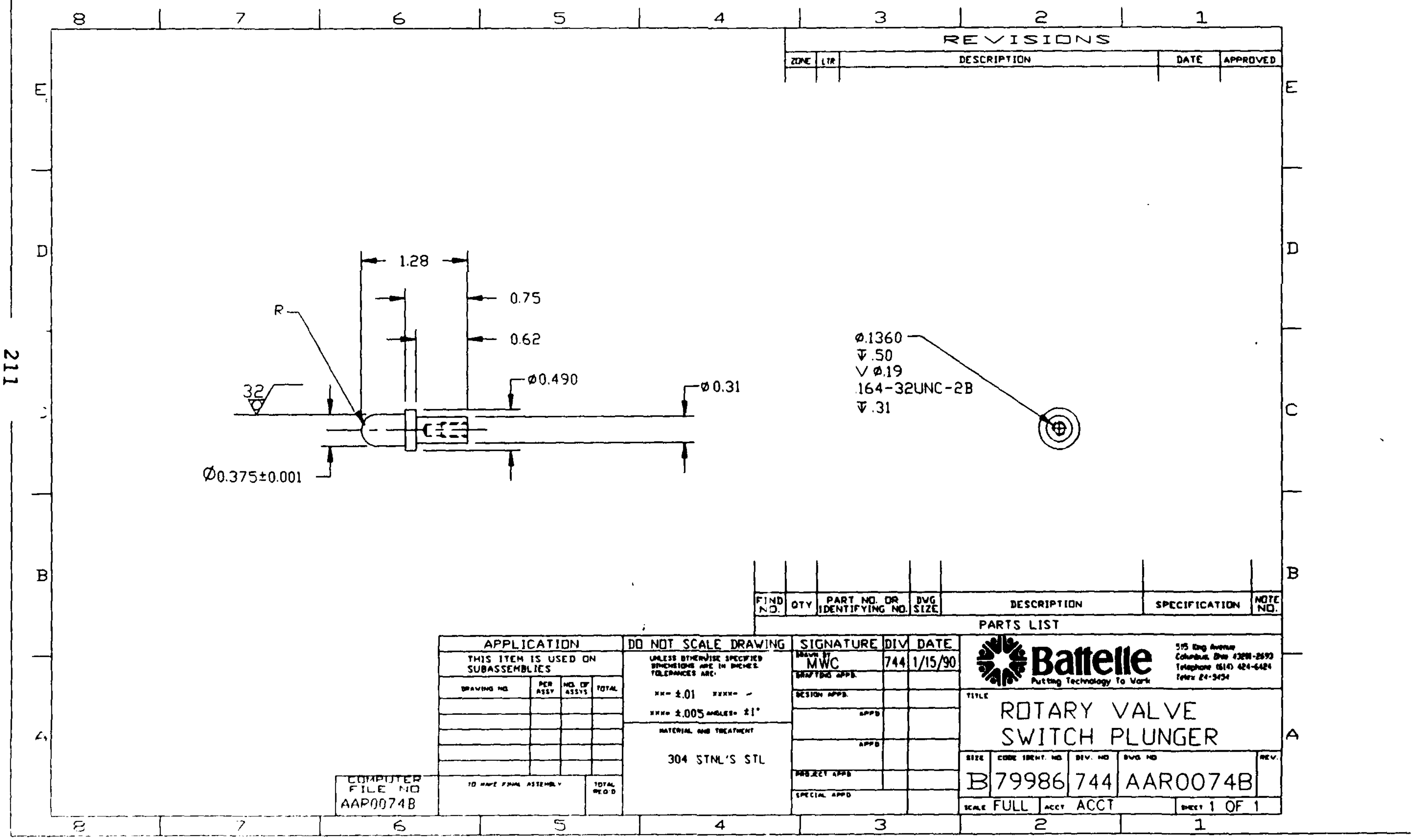
TITLE

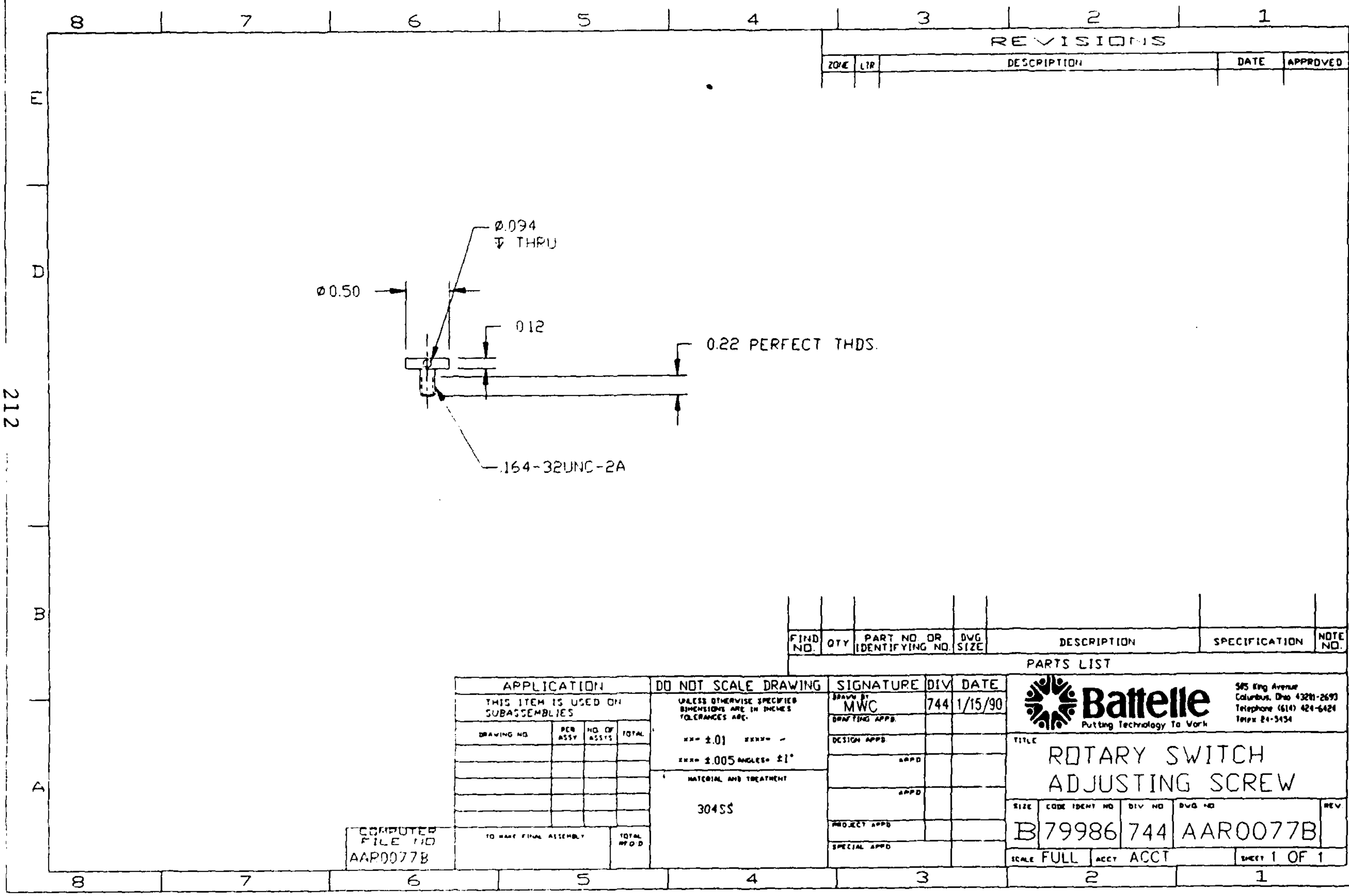
ROTARY VALVE
SWITCH MOUNT

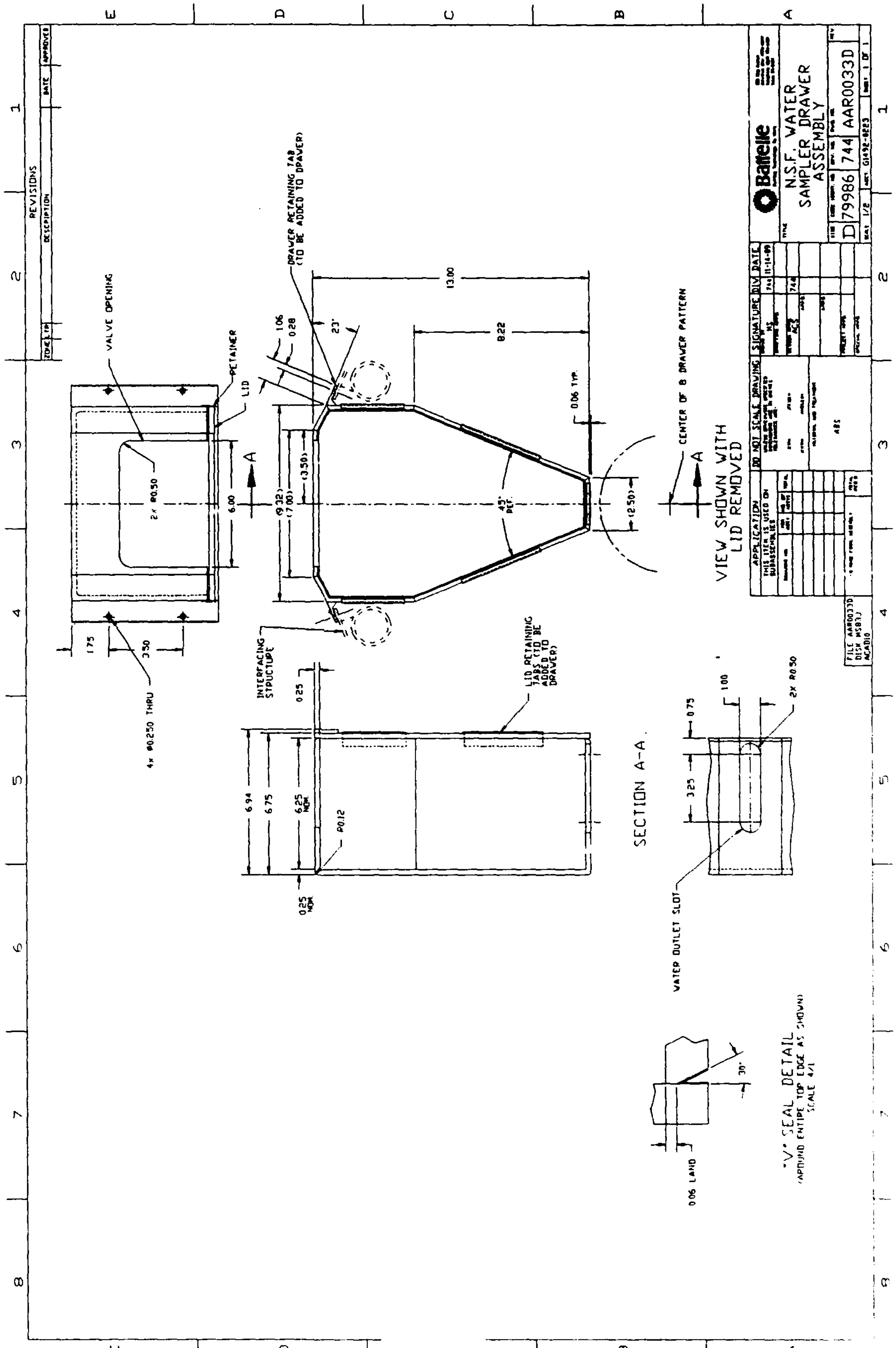
SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
C	79986	744	AAR0075C	

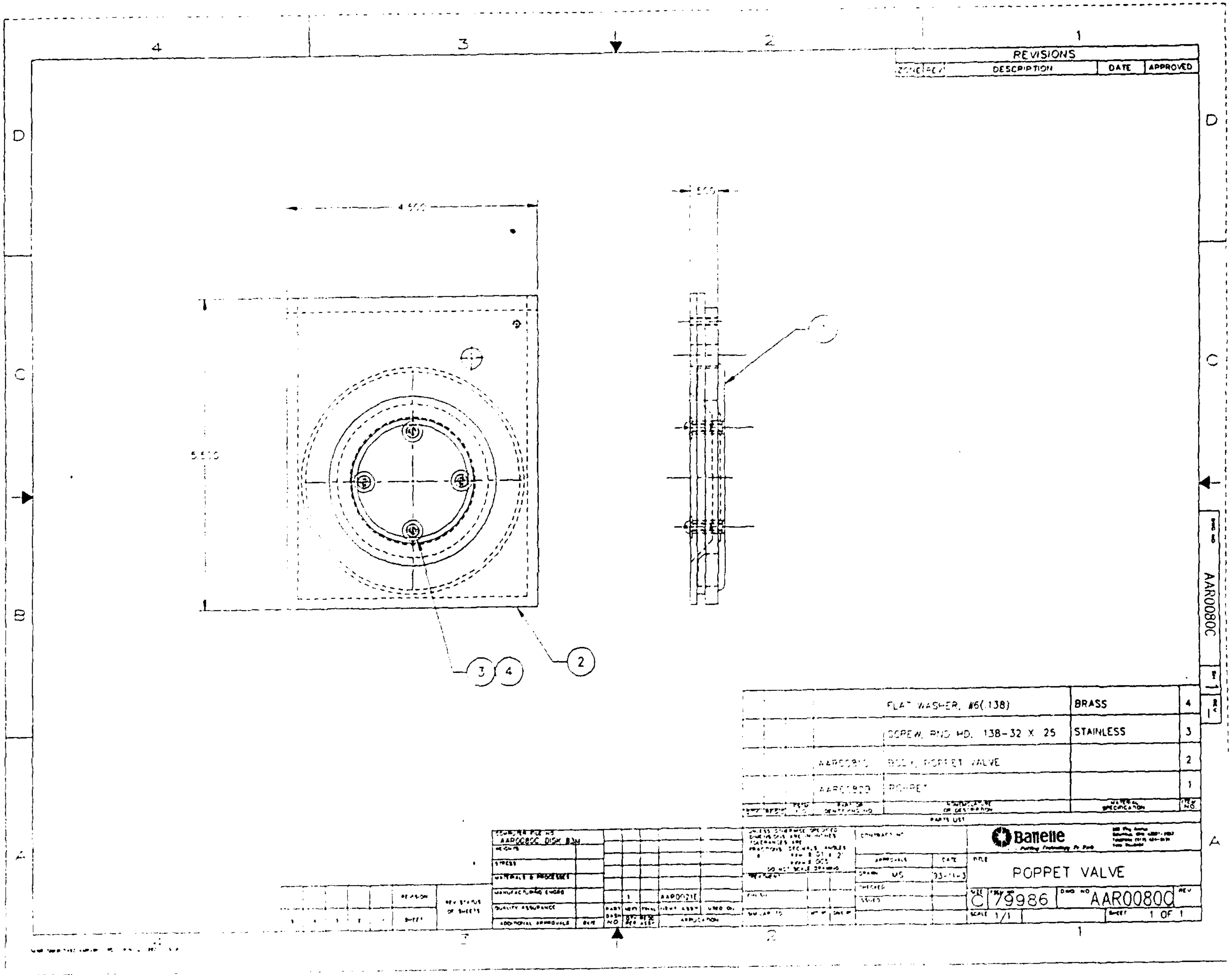
SCALE FULL ACCT. SHEET 1 OF 1

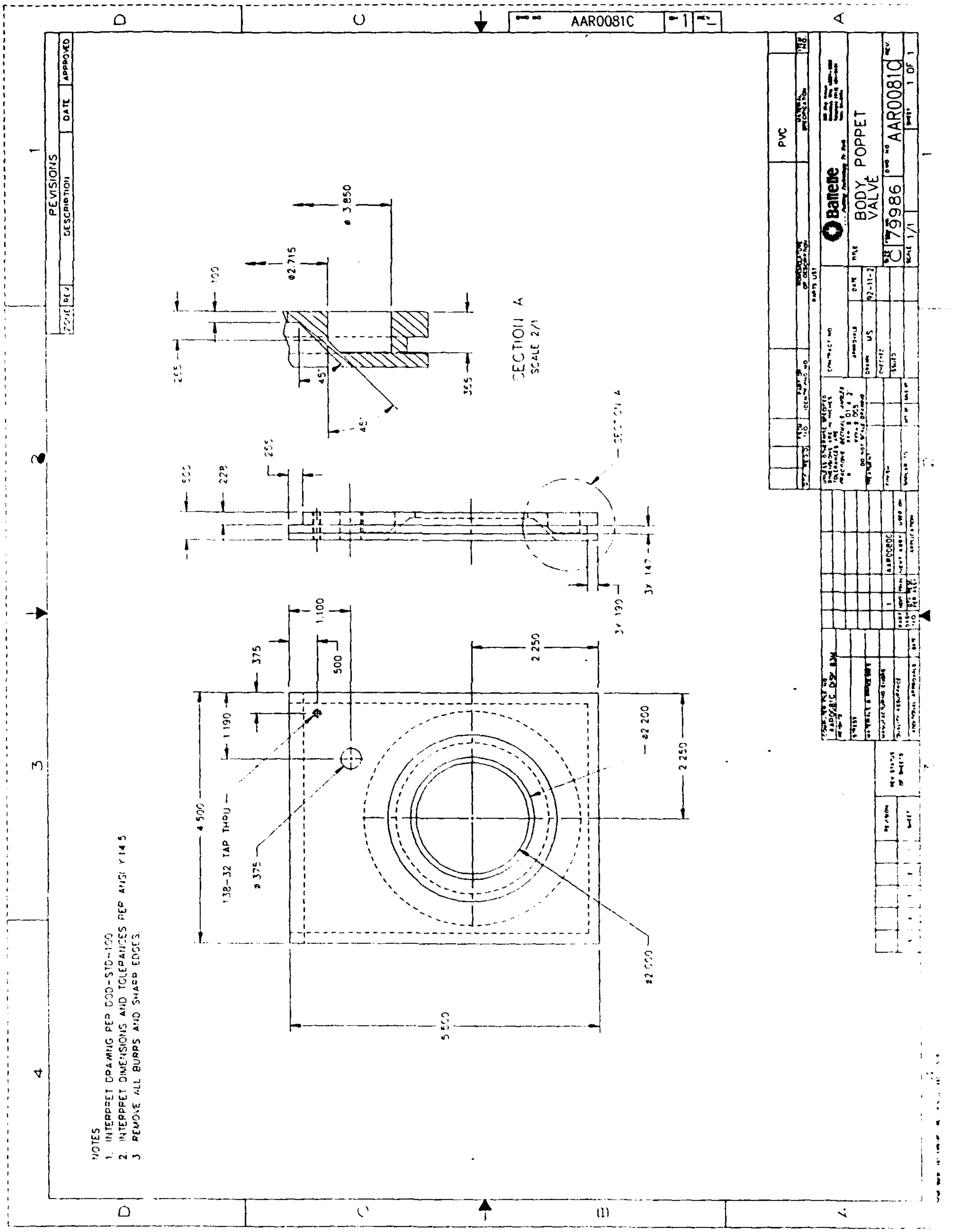
COMPUTER FILE AAP0075C

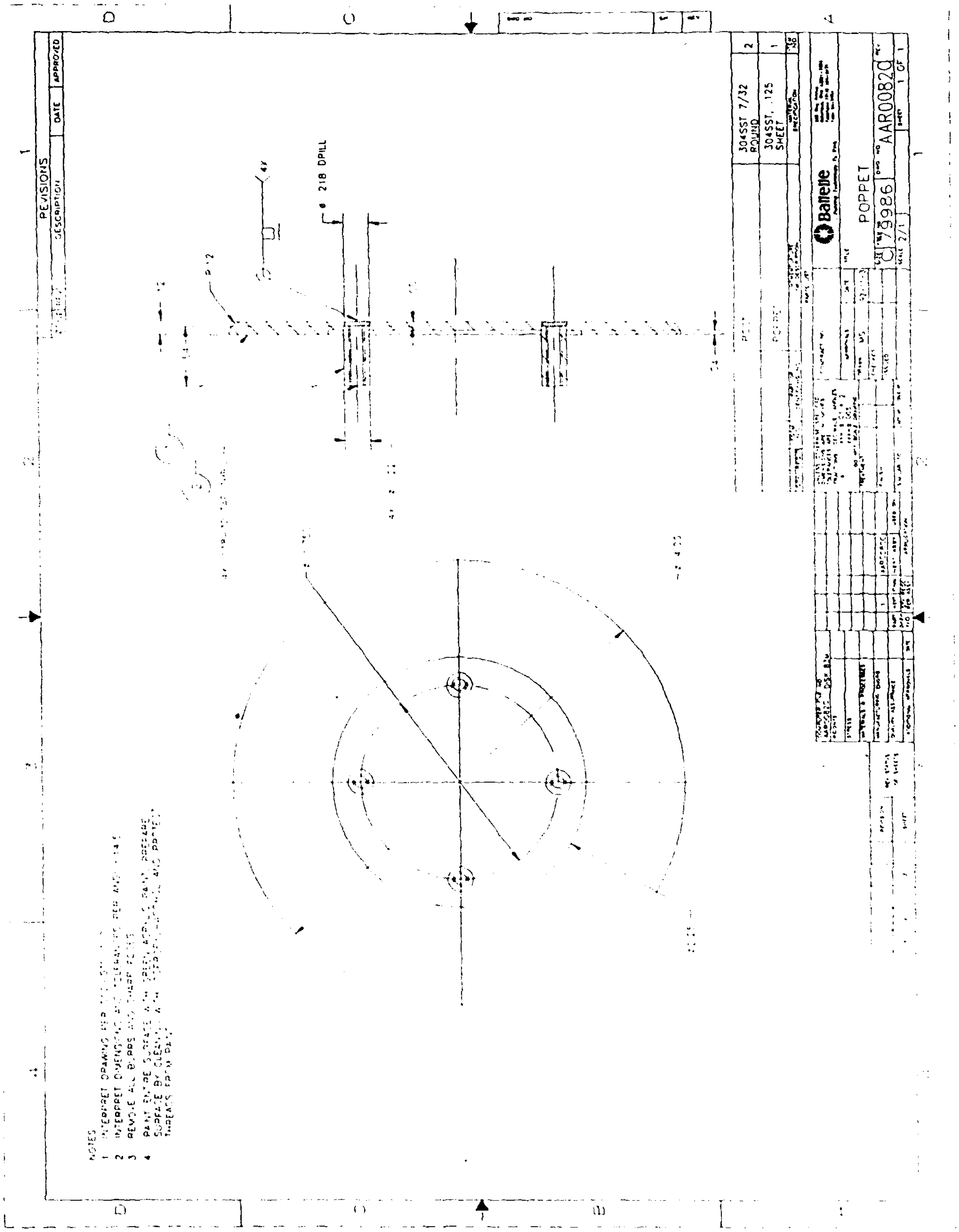

REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
1.28
0.75
0.62
R
32
⌀0.490
⌀0.31
⌀0.375±0.001
⌀.1360
⊽.50
V ⌀.19
.164-32UNC-2B
⊽.31
FIND NO.
QTY
PART NO. OR IDENTIFYING NO.
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DO NOT SCALE DRAWING
304 STNL'S STL
SIGNATURE
DIV
DATE
MWC
744
1/15/90
Battelle
Putting Technology To Work
ROTARY VALVE
SWITCH PLUNGER
B
79986
744
AAR0074B
FULL
ACCT
1 OF 1
COMPUTER FILE NO
AAP0074B

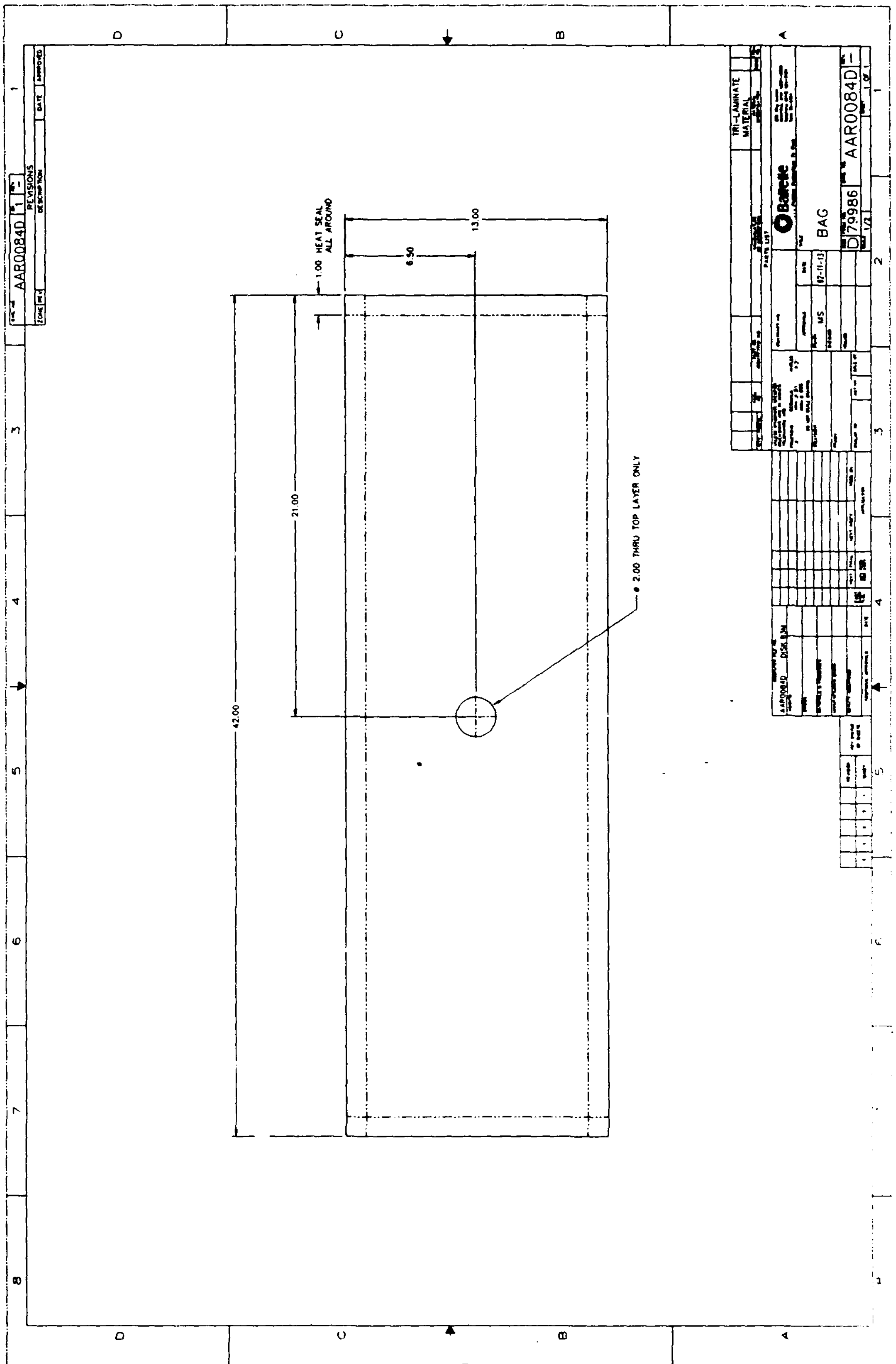

REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
ø.094
THRU
ø0.50
.012
0.22 PERFECT THDS.
.164-32UNC-2A
FIND NO. QTY PART NO. OR IDENTIFYING NO. DWG SIZE DESCRIPTION SPECIFICATION NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO. PER ASSY NO. OF ASSYS TOTAL
TO MAKE FINAL ASSEMBLY TOTAL MOD
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
.xxx ±.01
.xxxx ±.005 ANGLES ±1°
MATERIAL AND TREATMENT
304SS
SIGNATURE DIV DATE
DRAWN BY MWC 744 1/15/90
DRAFTING APPD
DESIGN APPD
APPD
APPD
PROJECT APPD
SPECIAL APPD
Battelle
Putting Technology To Work
505 King Avenue
Columbus, Ohio 43201-2693
Telephone (614) 424-6424
Telex 24-5454
TITLE
ROTARY SWITCH
ADJUSTING SCREW
SIZE B CODE IDENT NO 79986 DIV NO 744 DWG NO AAR0077B REV
SCALE FULL ACCT ACCT SHEET 1 OF 1
COMPUTER FILE NO
AAP0077B

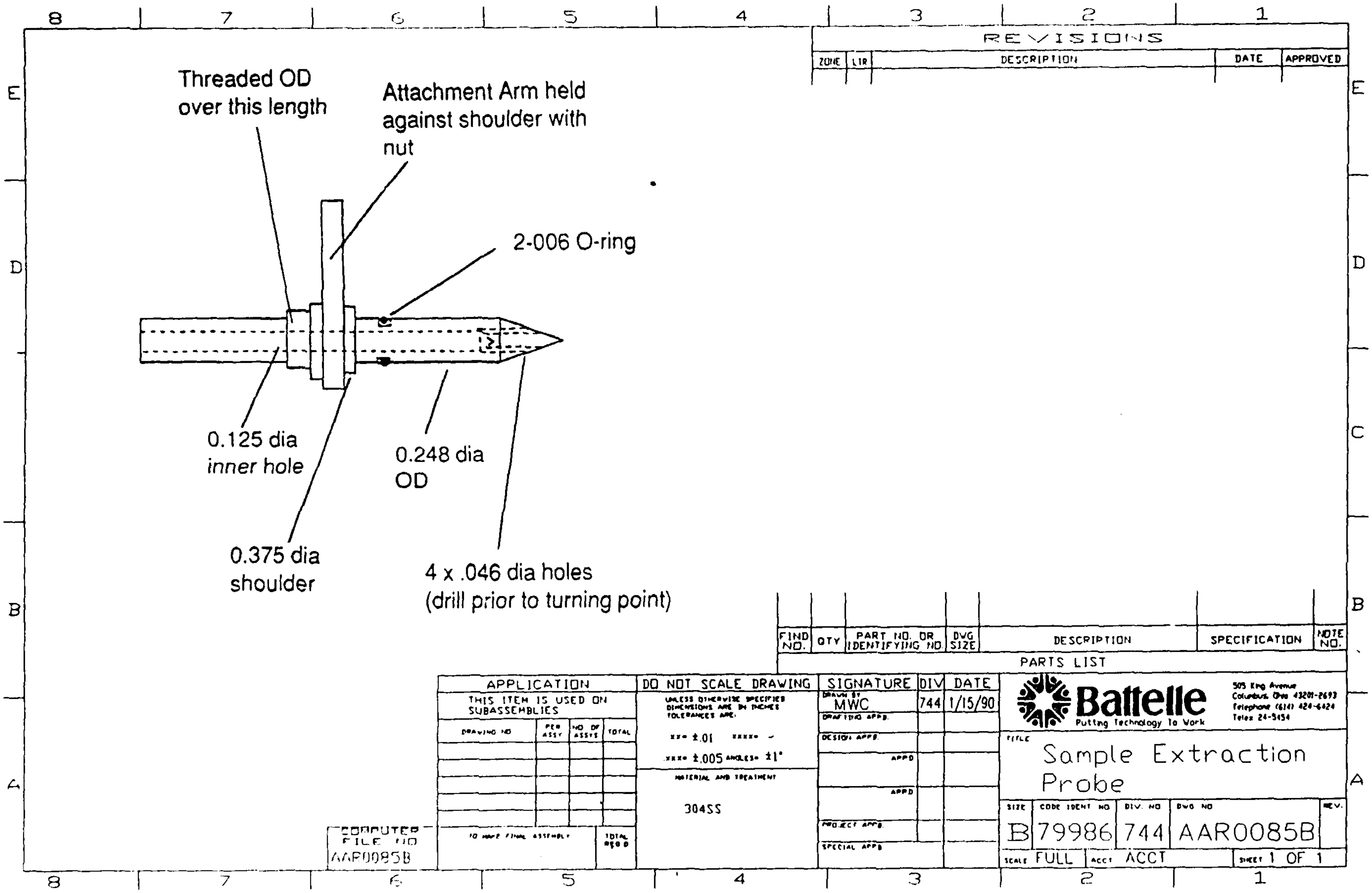

REVISIONS
VALVE OPENING
RETAINER
LID
2x R0.50
6.00
4x Ø0.250 THRU
DRAWER RETAINING TAB (TO BE ADDED TO DRAWER)
INTERFACING STRUCTURE
LID RETAINING TABS (TO BE ADDED TO DRAWER)
CENTER OF 8 DRAWER PATTERN
VIEW SHOWN WITH LID REMOVED
SECTION A-A
WATER OUTLET SLOT
"V" SEAL DETAIL
(AROUND ENTIRE TOP EDGE AS SHOWN)
SCALE 4/1
0.06 LAND
DO NOT SCALE DRAWING
Battelle
N.S.F. WATER SAMPLER DRAWER ASSEMBLY
D 79986 744 AAR0033D


REVISIONS
ZONE REV DESCRIPTION DATE APPROVED
4.500
5.500
.500
2
3
4
FLAT WASHER, #6(.138) BRASS 4
SCREW, RND HD, 138-32 X .25 STAINLESS 3
BODY, POPPET VALVE 2
POPPET 1
PARTS LIST
Battelle
POPPET VALVE
C 79986 AAR0080C
SCALE 1/1 SHEET 1 OF 1
AAR0080C


AAR0081C
REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
SECTION A
SCALE 2/1
138-32 TAP THRU
NOTES
1. INTERPRET DRAWING PER DOD-STD-100
2. INTERPRET DIMENSIONS AND TOLERANCES PER ANSI Y14.5
3. REMOVE ALL BURRS AND SHARP EDGES.
PVC
Battelle
BODY, POPPET
VALVE
C 79986 AAR0081C
SCALE 1/1
SHEET 1 OF 1
92-11-2


REVISIONS
DESCRIPTION
DATE
APPROVED
Ø .218 DRILL
4X
304SST 7/32 ROUND
304SST .125 SHEET
Battelle
POPPET
C
79986
AAR00820
2/1
1 OF 1


AAR0084D
REVISIONS
1.00 HEAT SEAL ALL AROUND
13.00
6.50
21.00
42.00
⌀ 2.00 THRU TOP LAYER ONLY
TRI-LAMINATE MATERIAL
Battelle
BAG
D 79986
AAR0084D
MS

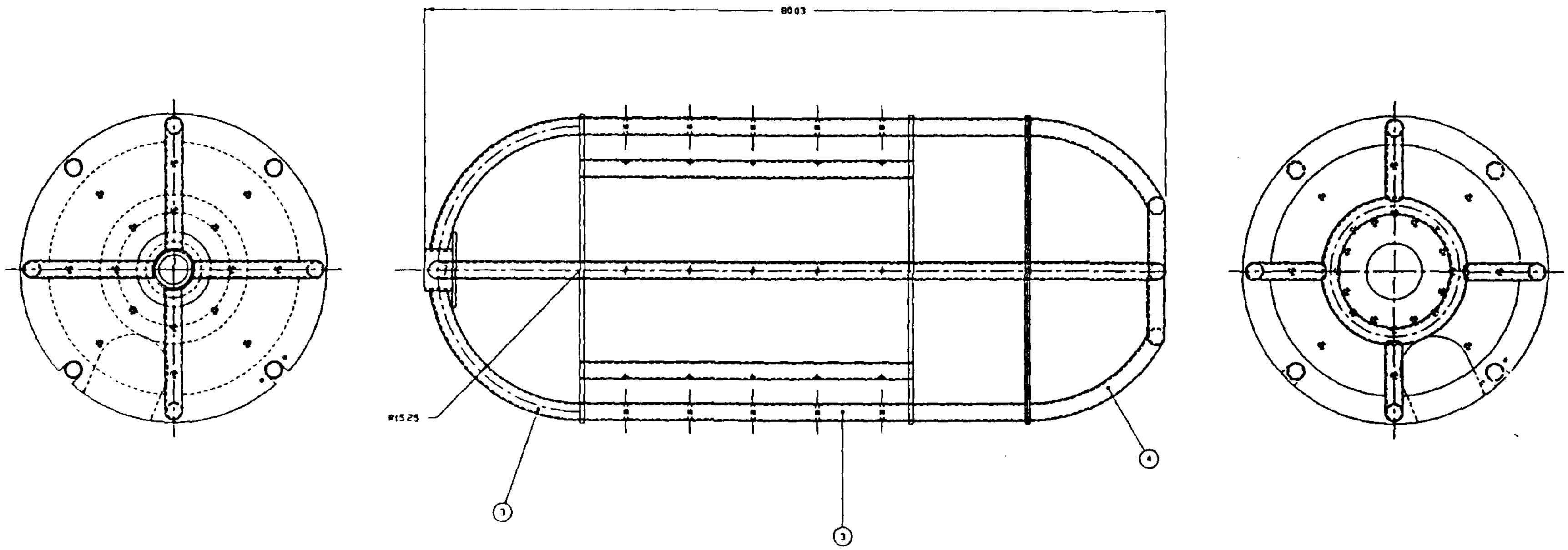

REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
Threaded OD over this length
Attachment Arm held against shoulder with nut
2-006 O-ring
0.125 dia inner hole
0.248 dia OD
0.375 dia shoulder
4 x .046 dia holes (drill prior to turning point)
FIND NO.
QTY
PART NO. OR IDENTIFYING NO
DWG SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DO NOT SCALE DRAWING
304SS
SIGNATURE
DIV
DATE
MWC
744
1/15/90
Battelle
Putting Technology To Work
Sample Extraction Probe
B
79986
744
AAR0085B
FULL
ACCT
SHEET 1 OF 1
COMPUTER FILE NO
AAR0085B

C: Mechanical Drawings (WHOI)

Water Sampler Frame	
General Frame Assembly	D051-002
Upper Frame Assembly	D051-003
Lower Frame Assembly	D051-004
Buoyancy Compensation	D051-015
Top Bulkhead Plate	D051-005
Bottom Bulkhead Plate	D051-006
Annulus Support Plate	D051-007
Pipe	D051-008
Wire Housing Pipe	D051-009
Upper Frame Pipe	D051-010
Apex Coupling Assembly	D051-011
Clevis/Load Cell Bolt	D051-020
Termination Collar	D052-003
Apex Coupling Plate	D051-012
Apex Coupling Ring	D051-013
Frame Apex Coupling	D051-014
Termination	
General Termination Assembly	D052-011
Male Tapered Plug Sleeve	D052-009
Female Tapered Plug Sleeve	D052-010
Male Termination Alternative	D052-021
Female Termination Alternative	D052-022
Pressure Case/Electronics Racks	
Pressure Case:	
Bottom End Cap	D053-006
Top End Cap	D053-007
Pressure Cylinder	D053-004
Engineering Module:	
Top End Cap	D053-010
Bottom End Cap	D053-011
Assembly	D053-020
Support Plate	D053-025
Side Plate	D053-022
Base Plate	D053-023
Top End Plate	D053-021
Bottom End Plate	D053-024
End Plate Standoff	D053-026
Electronics Controller	
Top End Cap	D053-008
Bottom End Cap	D053-009
Electronics Rack:	
Middle Plate	D053-046
Top Plate	D053-047
Bottom Plate	D053-045
Vertical Plate	D053-048
Unlabeled Plate	

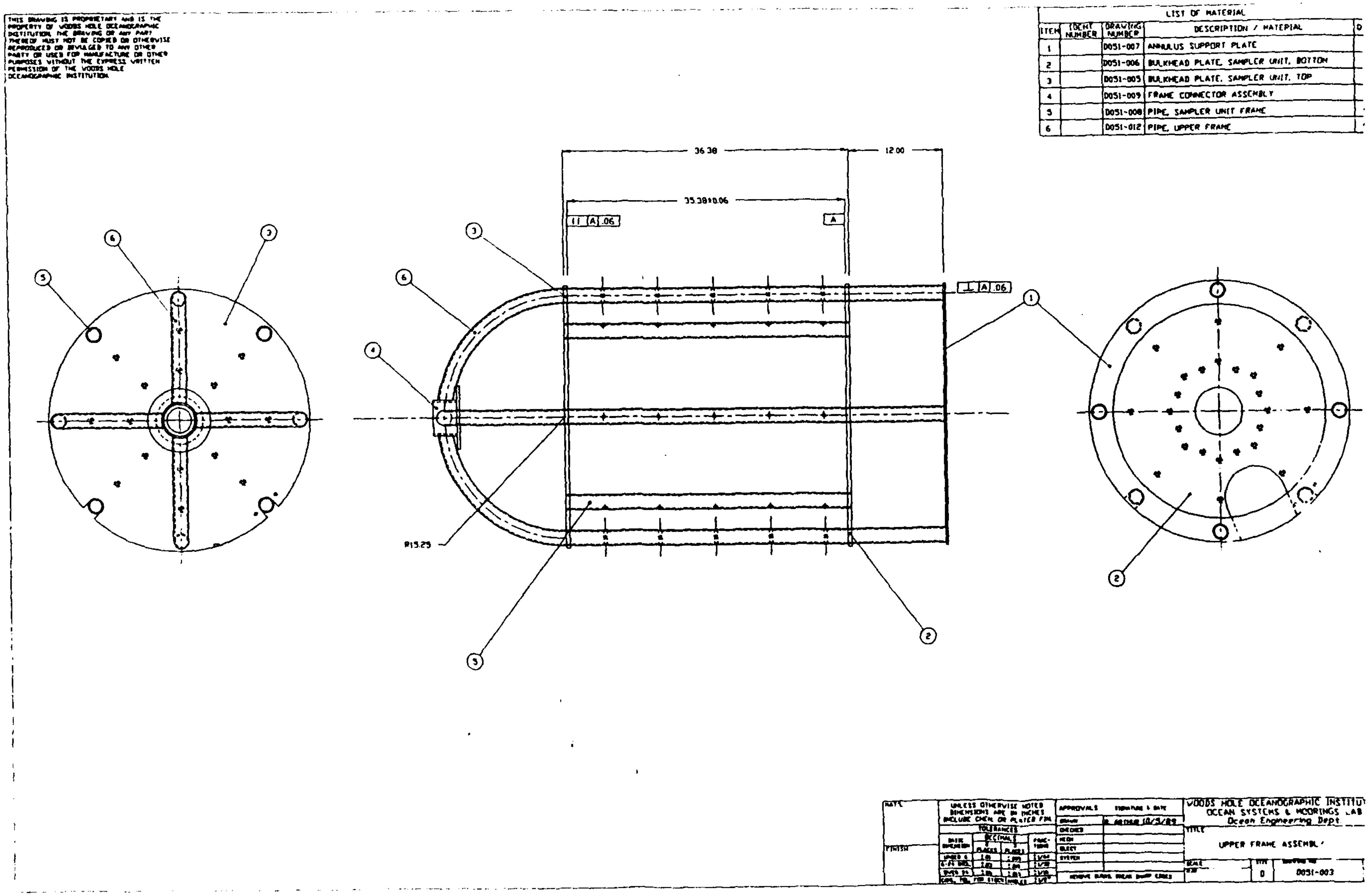
LIST OF MATERIAL

ITEM	IDENT NUMBER	DRAWING NUMBER	DESCRIPTION / MATERIAL	Q
1		D051-003	UPPER FRAME ASSEMBLY	
2		D051-004	LOWER FRAME ASSEMBLY	



FOR PROTOTYPE MOCKUP USE ONLY

MAT'L	UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN. TOLERANCES	APPROVALS / SIGNATURE & DATE	WOODS HOLE OCEANOGRAPHIC INSTITUTION OCEAN SYSTEMS & MOORINGS LAB Ocean Engineering Dept.
FINISH		DRAWN: R. ARTHUR 10/5/89	TITLE: FRAME GENERAL ASSEMBLY
		CHECKED	SIZE: D
		REMOVE BURRS, BREAK SHARP EDGES	DRAWING NO. D051-002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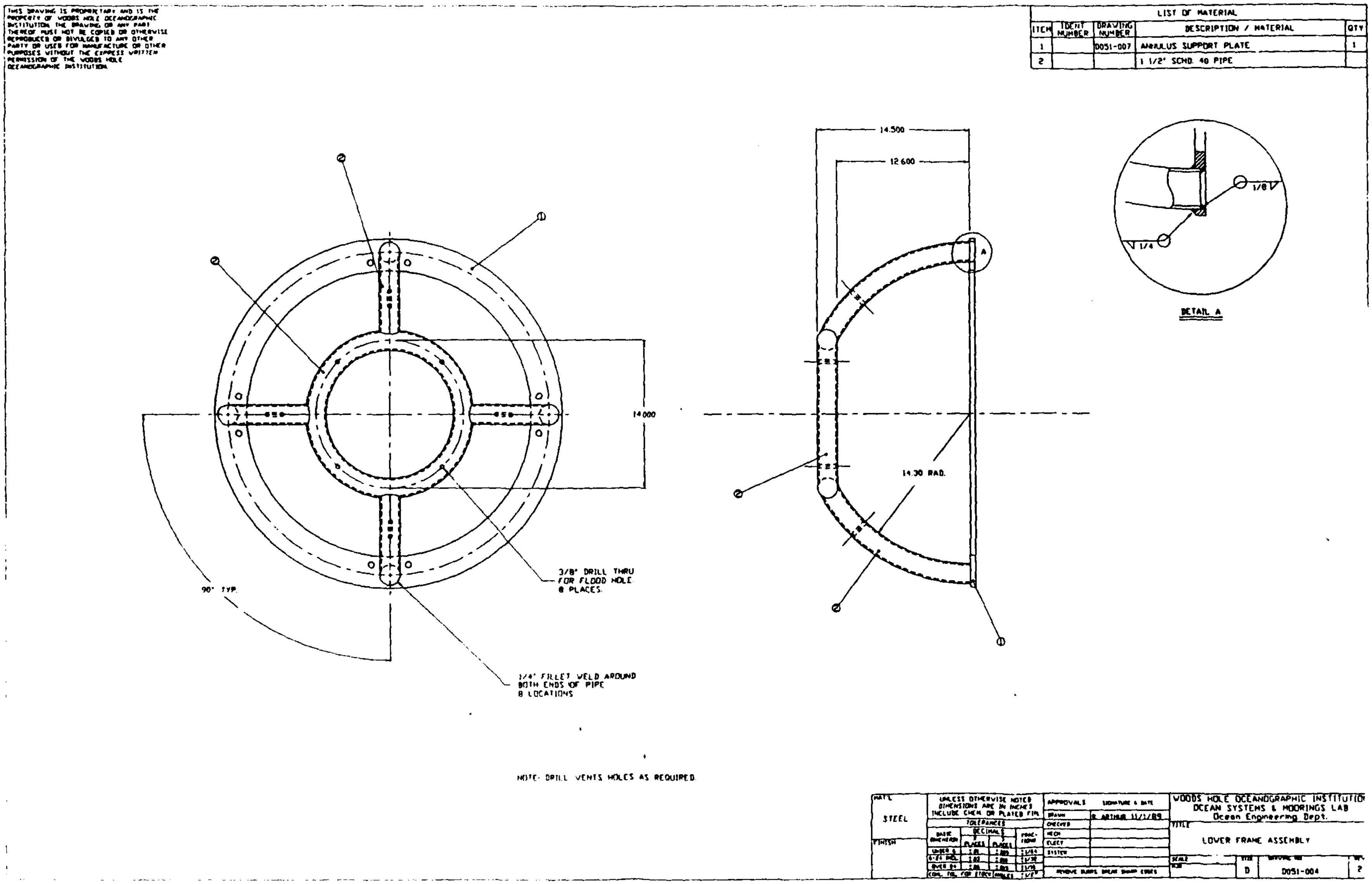
LIST OF MATERIAL
ITEM | IDENT NUMBER | DRAWING NUMBER | DESCRIPTION / MATERIAL
1 | | D051-007 | ANNULUS SUPPORT PLATE
2 | | D051-006 | BULKHEAD PLATE, SAMPLER UNIT, BOTTOM
3 | | D051-005 | BULKHEAD PLATE, SAMPLER UNIT, TOP
4 | | D051-009 | FRAME CONNECTOR ASSEMBLY
5 | | D051-008 | PIPE, SAMPLER UNIT FRAME
6 | | D051-012 | PIPE, UPPER FRAME
36.38
12.00
35.38±0.06
A
.06
R15.25
1
2
3
4
5
6
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
TOLERANCES
APPROVALS
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept
TITLE
UPPER FRAME ASSEMBLY
D
D051-003
MATL
FINISH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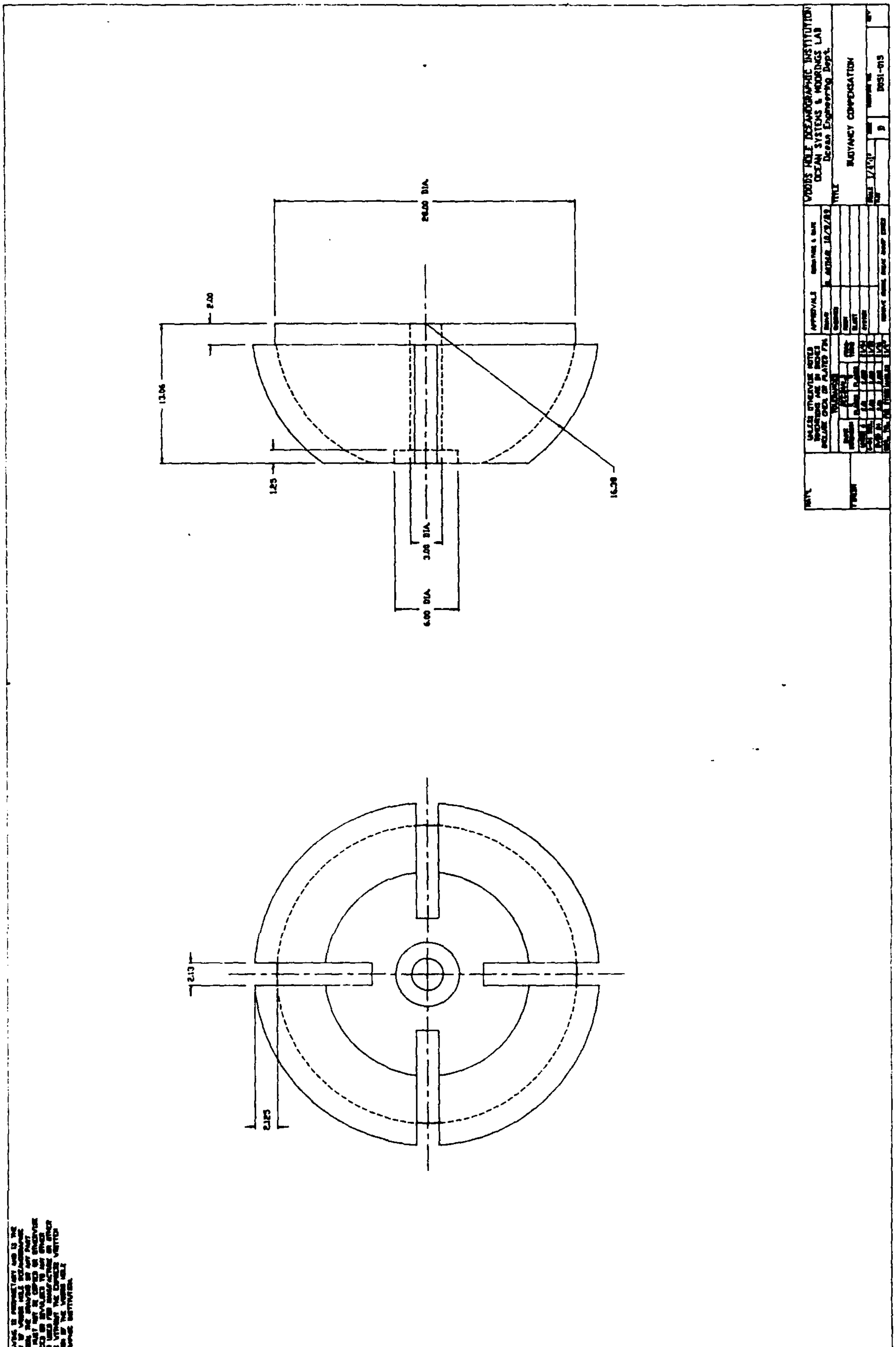
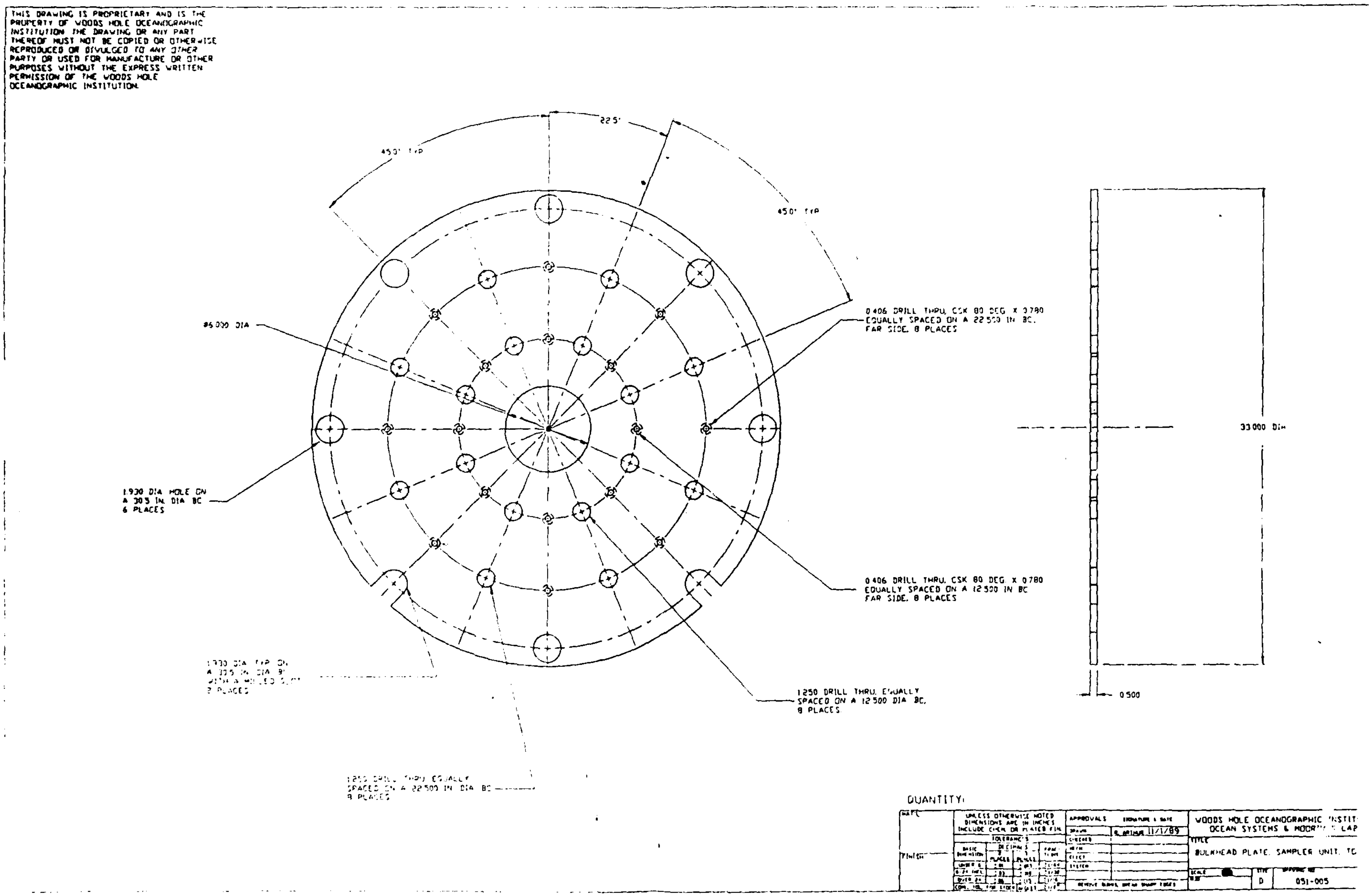
LIST OF MATERIAL
ITEM | IDENT NUMBER | DRAWING NUMBER | DESCRIPTION / MATERIAL | QTY
1 | | D051-007 | ANNULUS SUPPORT PLATE | 1
2 | | | 1 1/2" SCHD. 40 PIPE |
14.500
12.600
14.000
14.30 RAD.
90° TYP.
3/8" DRILL THRU FOR FLOOD HOLE 8 PLACES.
1/4" FILLET WELD AROUND BOTH ENDS OF PIPE 8 LOCATIONS
1/8
1/4
A
DETAIL A
NOTE: DRILL VENTS HOLES AS REQUIRED.
MAT'L STEEL
FINISH
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
APPROVALS
SIGNATURE & DATE
DRAWN
R. ARTHUR 11/1/89
CHECKED
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept.
TITLE
LOWER FRAME ASSEMBLY
D
D051-004
2


WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept.
BUOYANCY COMPENSATION
24.00 DIA
2.00
13.06
1.25
16.38
3.00 DIA
6.00 DIA
2.13
2.125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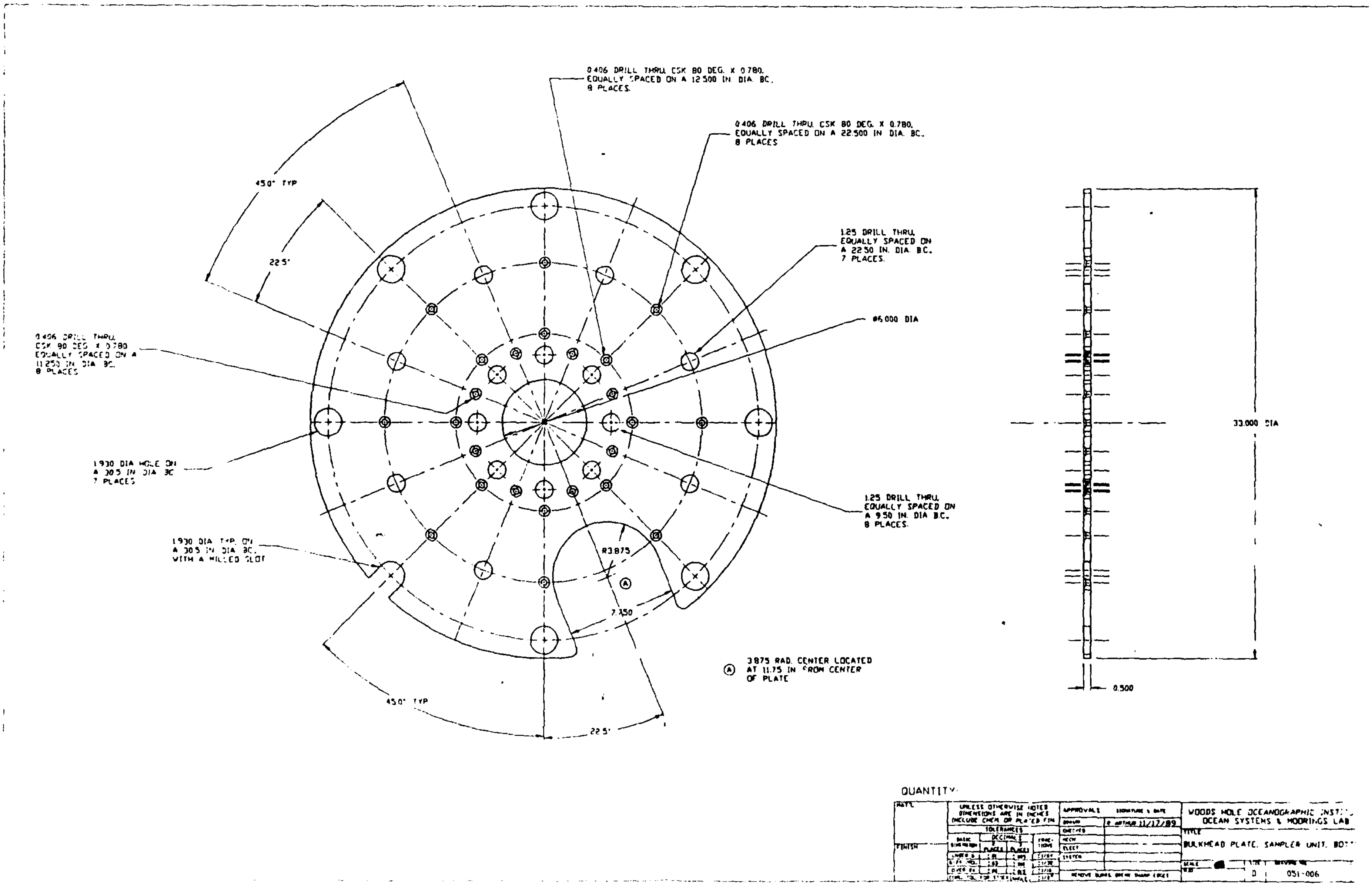
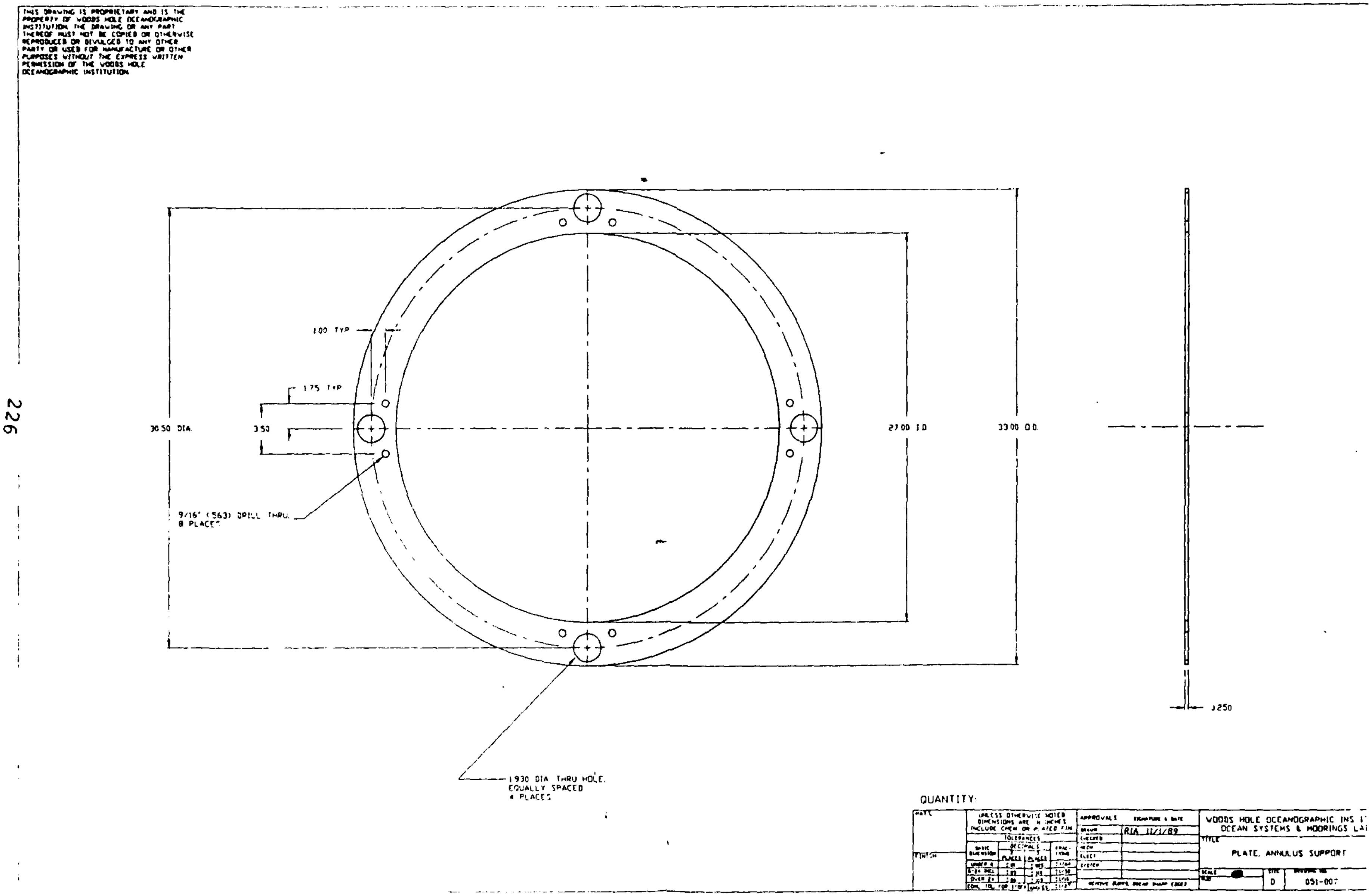
22.5°
45.0° TYP
45.0° TYP
6.000 DIA
0.406 DRILL THRU, CSK 80 DEG X 0.780 EQUALLY SPACED ON A 22.500 IN BC, FAR SIDE, 8 PLACES
1.930 DIA HOLE ON A 30.5 IN DIA BC 6 PLACES
0.406 DRILL THRU, CSK 80 DEG X 0.780 EQUALLY SPACED ON A 12.500 IN BC FAR SIDE, 8 PLACES
1.250 DRILL THRU, EQUALLY SPACED ON A 12.500 DIA BC, 8 PLACES
1.250 DRILL THRU EQUALLY SPACED ON A 22.500 IN DIA BC 8 PLACES
33.000 DIA
0.500
QUANTITY:
MAT'L
FINISH
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
TOLERANCES
APPROVALS
DRAWN
11/1/89
CHECKED
WOODS HOLE OCEANOGRAPHIC INSTIT
OCEAN SYSTEMS & MOORING LAB
TITLE
BULKHEAD PLATE, SAMPLER UNIT, TC
SCALE
SIZE
D
051-005


0.406 DRILL THRU, CSK 80 DEG. X 0.780, EQUALLY SPACED ON A 12.500 IN. DIA. BC, 8 PLACES.
0.406 DRILL THRU, CSK 80 DEG. X 0.780, EQUALLY SPACED ON A 22.500 IN. DIA. BC, 8 PLACES
1.25 DRILL THRU, EQUALLY SPACED ON A 22.50 IN. DIA. BC, 7 PLACES.
ø6.000 DIA
1.25 DRILL THRU, EQUALLY SPACED ON A 9.50 IN. DIA. BC, 8 PLACES.
0.406 DRILL THRU CSK 90 DEG X 0.780 EQUALLY SPACED ON A 11.250 IN. DIA. BC. 8 PLACES
1.930 DIA HOLE ON A 30.5 IN DIA BC 7 PLACES
1.930 DIA TYP. ON A 30.5 IN DIA BC, WITH A MILLED SLOT
45.0° TYP
22.5°
45.0° TYP
22.5°
R3.875
7.750
Ⓐ 3.875 RAD. CENTER LOCATED AT 11.75 IN FROM CENTER OF PLATE
33.000 DIA
0.500
QUANTITY
WOODS HOLE OCEANOGRAPHIC INSTIT. OCEAN SYSTEMS & MOORINGS LAB
BULKHEAD PLATE, SAMPLER UNIT, BOT
D
051-006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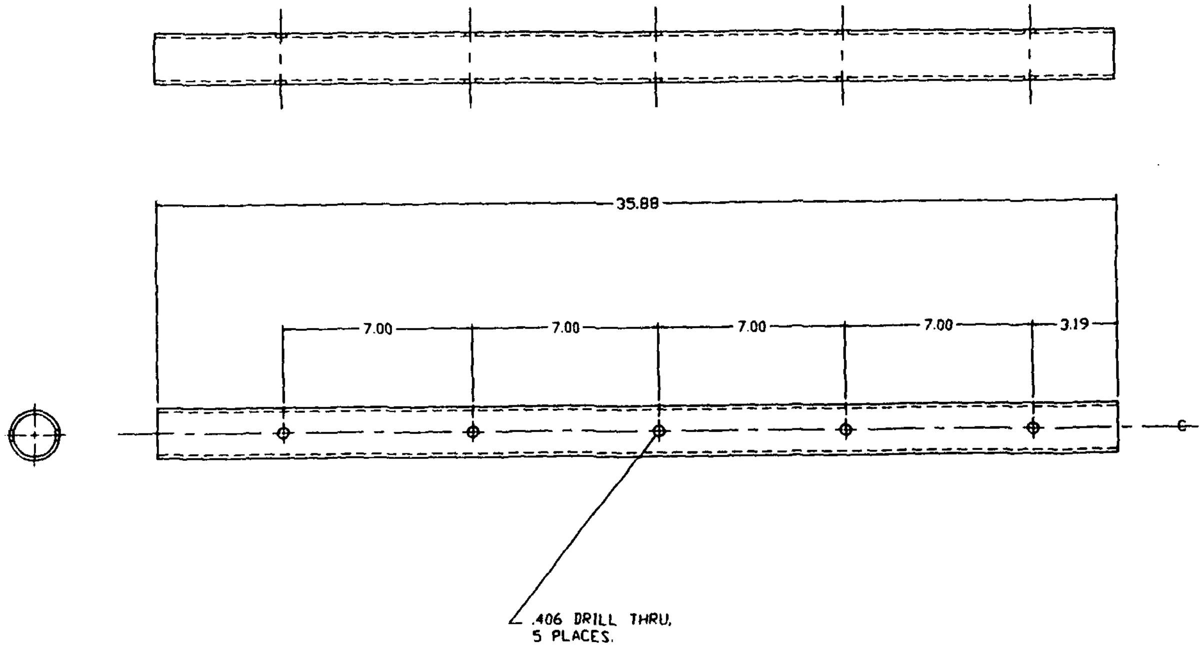
100 TYP
175 TYP
3050 DIA
350
2700 ID
3300 OD
9/16" (.563) DRILL THRU
8 PLACES
.250
1.930 DIA THRU HOLE
EQUALLY SPACED
4 PLACES
QUANTITY:
RJA 11/1/89
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
PLATE, ANNULUS SUPPORT
D
051-007



QUANTITY:

MAT'L: 1-1/2" SCHD. 40 PIPE

FINISH:

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.

TOLERANCES

BASIC DIMENSION	DECIMALS 2 PLACES	DECIMALS 3 PLACES	FRAC-TIONS
UNDER 6	±.01	±.005	±1/64
6-24 INCL.	±.03	±.010	±1/32
OVER 24	±.06	±.015	±1/16

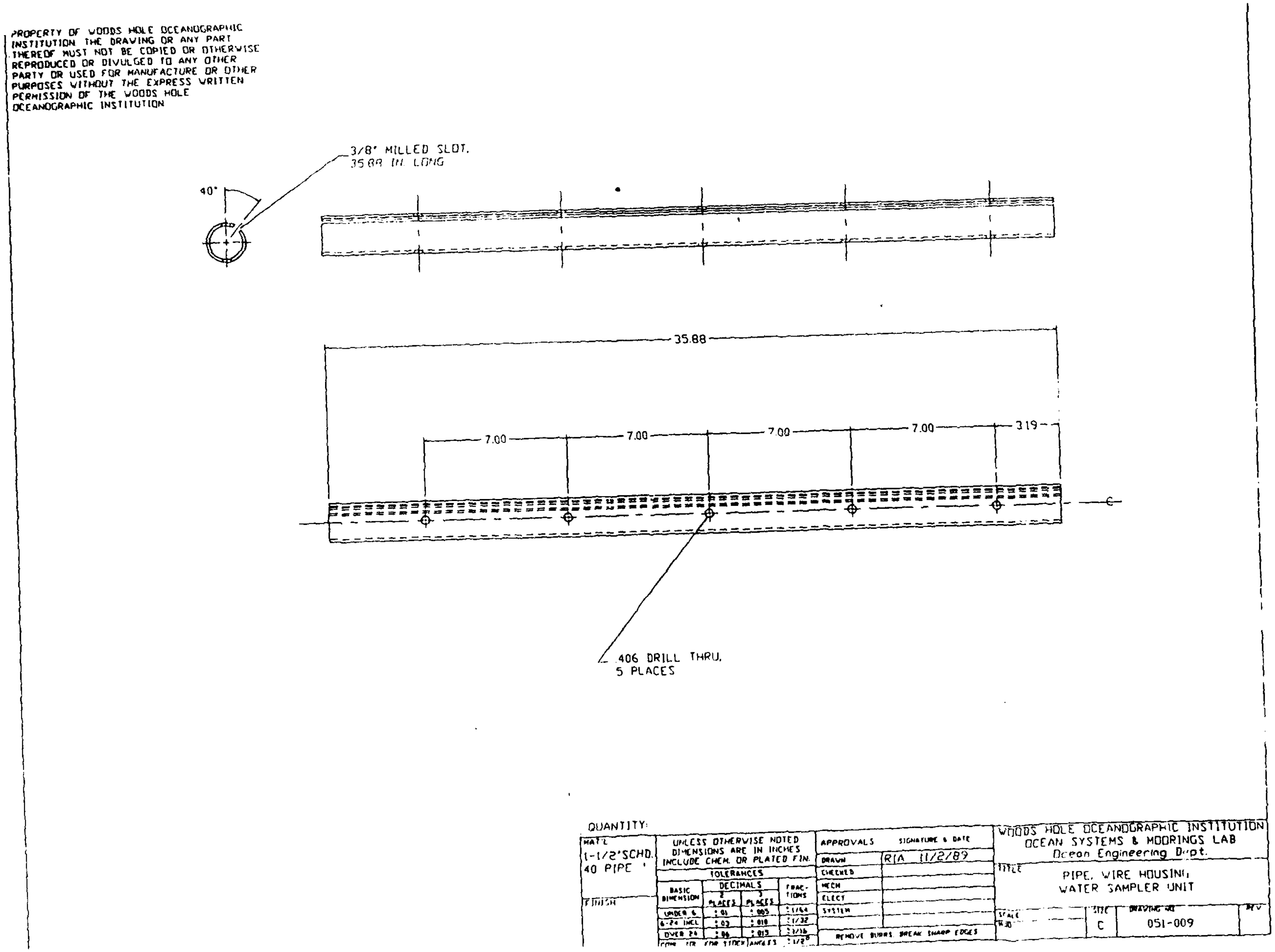
APPROVALS	SIGNATURE & DATE
DRAWN	RJA 11/1/89
CHECKED	
MECH	
ELECT	
SYSTEM	

REMOVE BURRS, BREAK SHARP EDGES

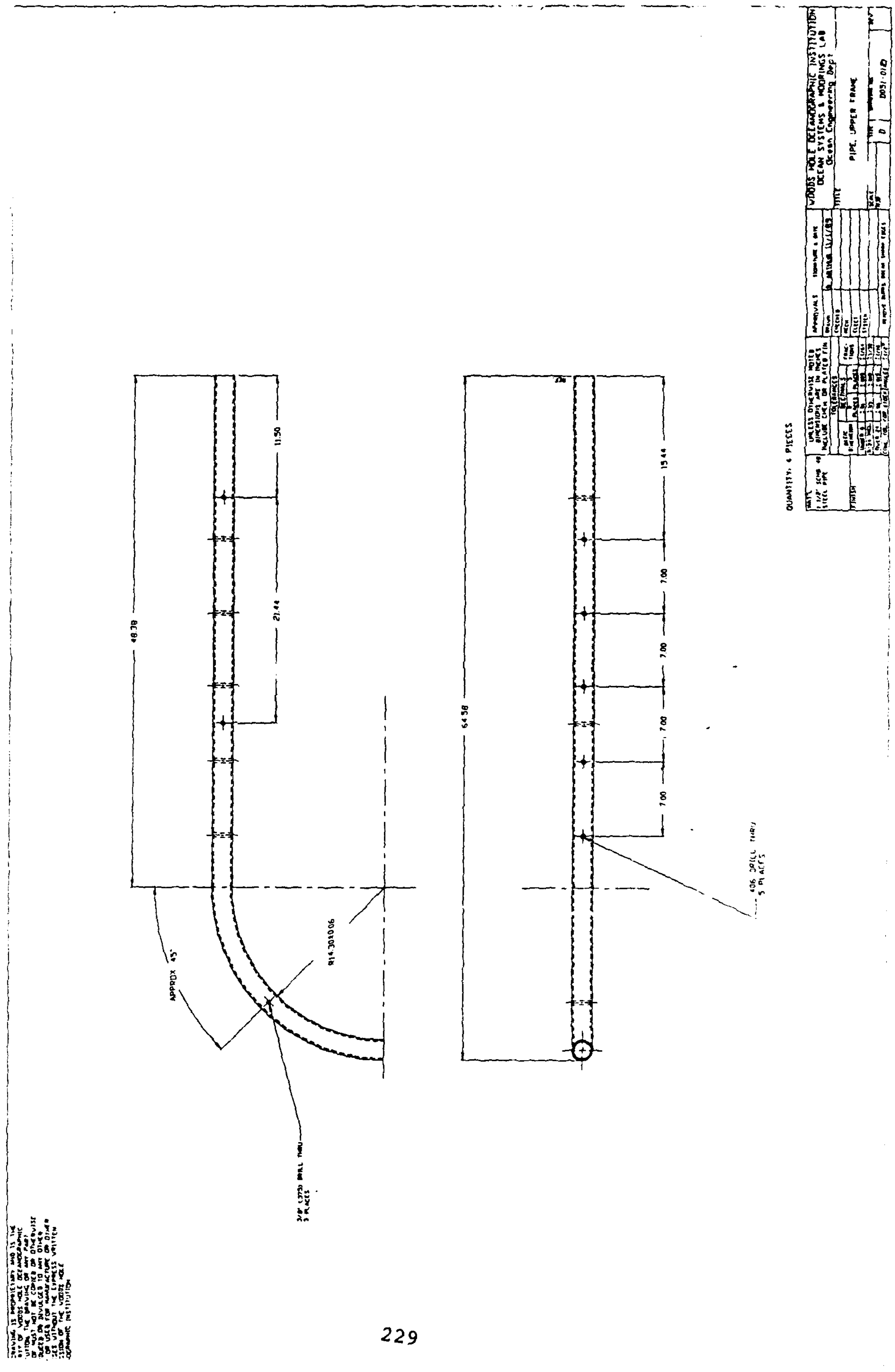
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept.

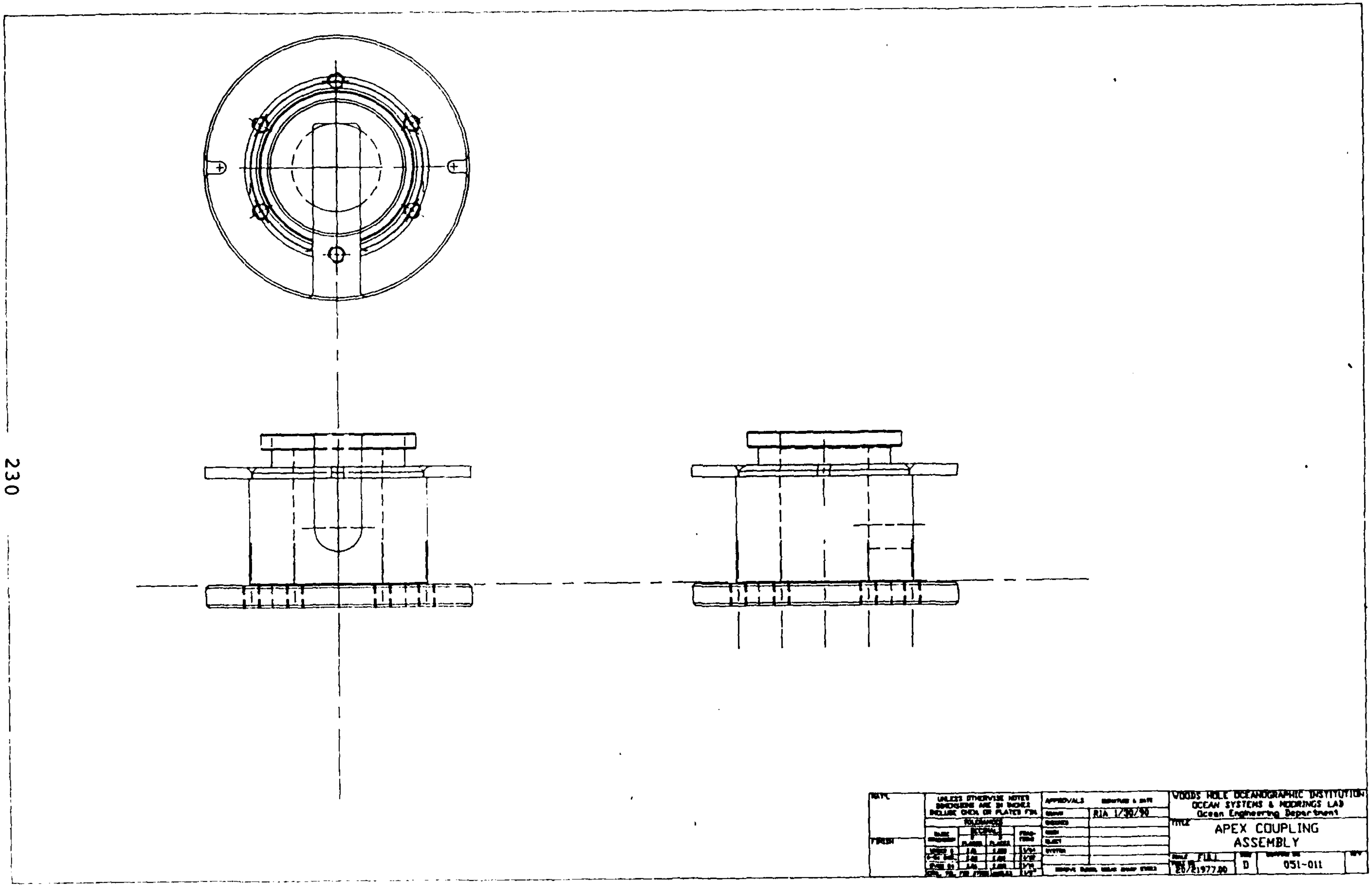
TITLE: PIPE, WATER SAMPLER UNIT

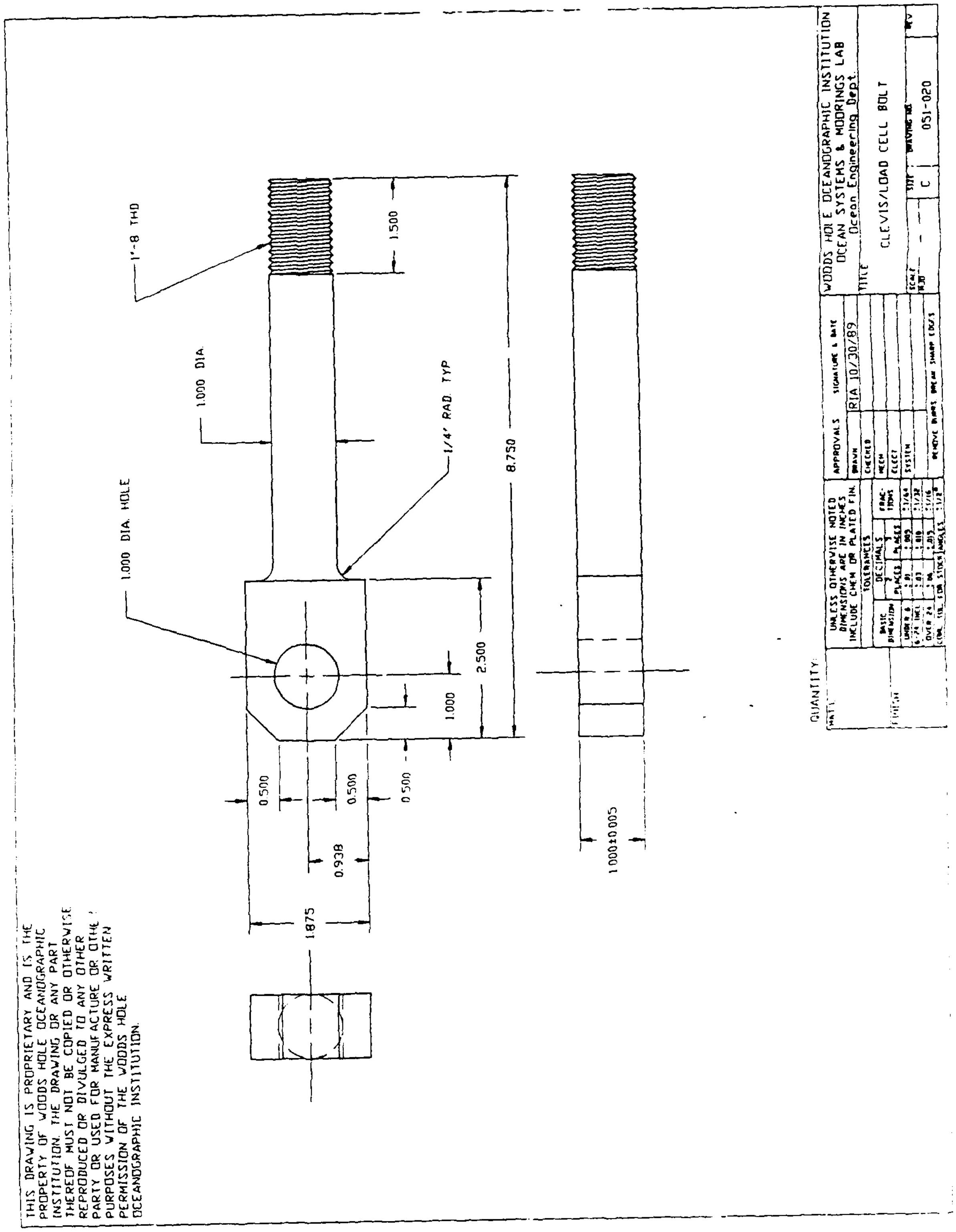
SCALE:
SIZE: C
DRAWING NO.: 051-008
REV:

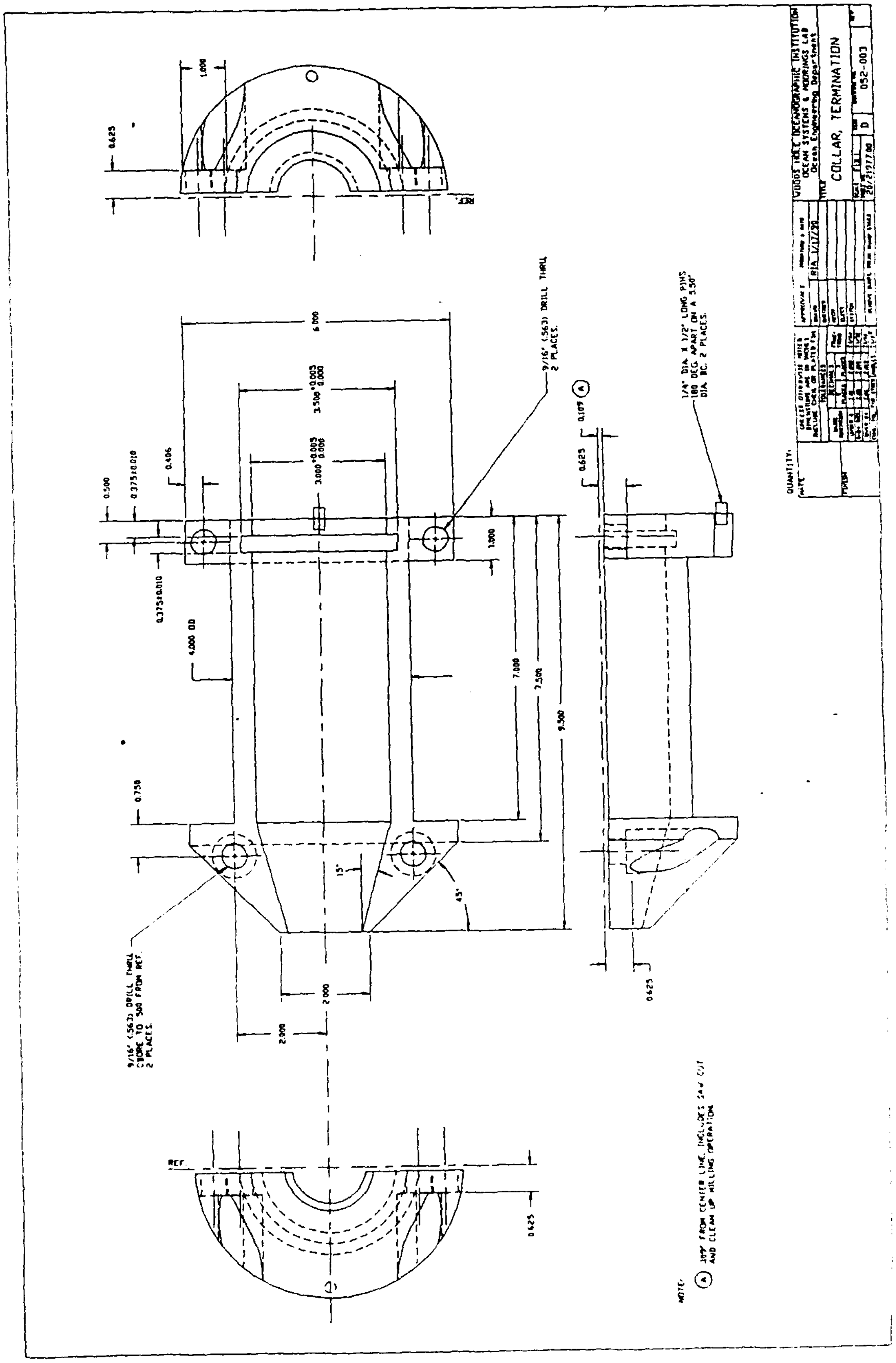


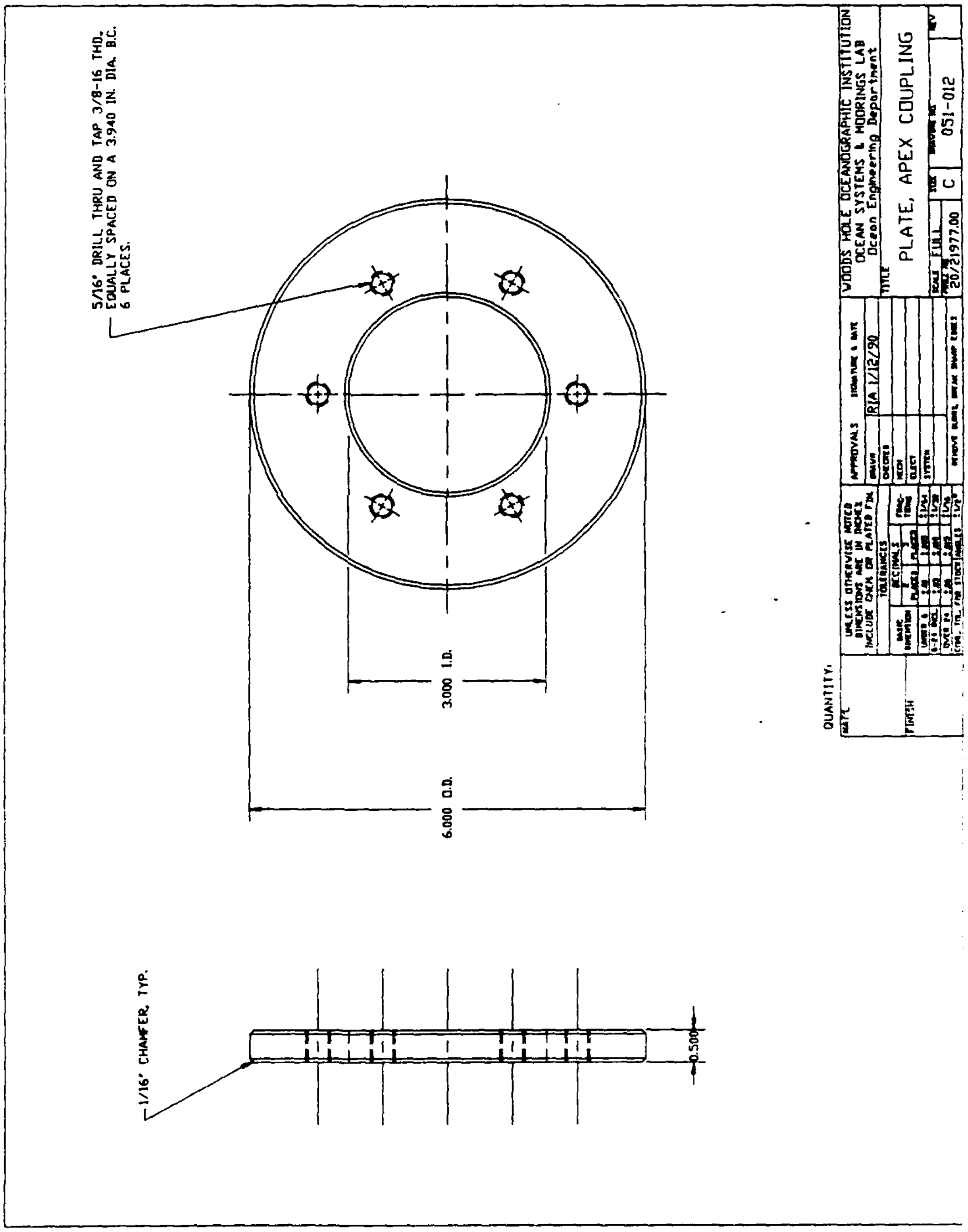
PROPERTY OF WOODS HOLE OCEANOGRAPHIC INSTITUTION THE DRAWING OR ANY PART THEREOF MUST NOT BE COPIED OR OTHERWISE REPRODUCED OR DIVULGED TO ANY OTHER PARTY OR USED FOR MANUFACTURE OR OTHER PURPOSES WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE WOODS HOLE OCEANOGRAPHIC INSTITUTION
3/8" MILLED SLOT, 35.88 IN. LONG
40°
35.88
7.00
7.00
7.00
7.00
3.19
.406 DRILL THRU, 5 PLACES
QUANTITY:
MAT'L 1-1/2" SCHD. 40 PIPE
FINISH
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
APPROVALS
SIGNATURE & DATE
DRAWN R/A 11/2/89
CHECKED
MECH
ELECT
SYSTEM
REMOVE BURRS BREAK SHARP EDGES
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept.
TITLE
PIPE, WIRE HOUSING
WATER SAMPLER UNIT
SCALE
SIZE C
DRAWING NO. 051-009
REV


WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept
TITLE
PIPE, UPPER FRAME
D051-01D
MATL
1 1/2" SCHD 40 STEEL PIPE
FINISH
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
TOLERANCES
APPROVALS
QUANTITY: 4 PIECES
48.38
11.50
21.44
64.38
15.44
7.00
7.00
7.00
7.00
APPROX 45°
R14.30±0.06
3/8" (.375) DRILL THRU
5 PLACES
.406 DRILL THRU
5 PLACES

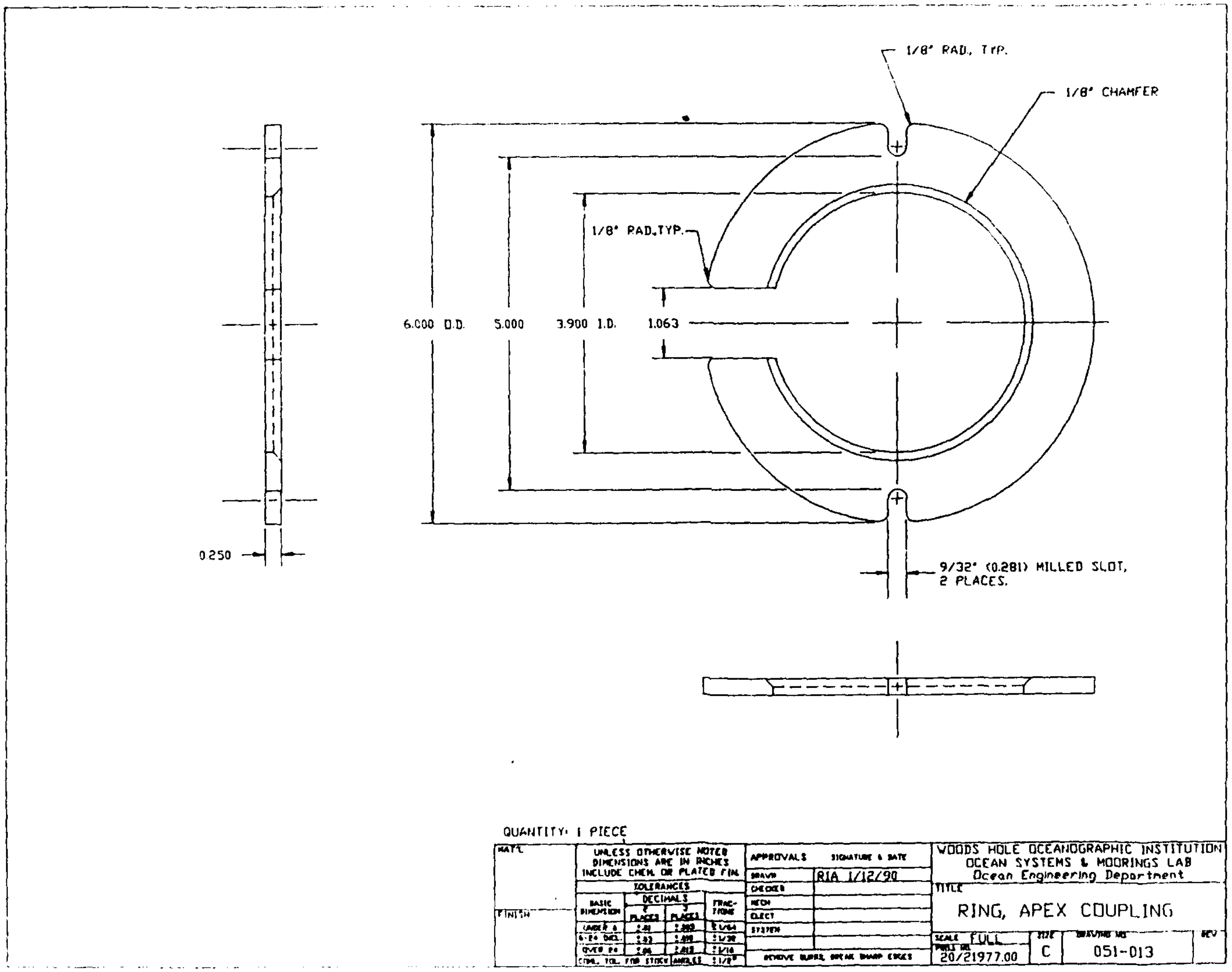

WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
APEX COUPLING
ASSEMBLY
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
APPROVALS
RIA 1/30/90
FULL
D
051-011

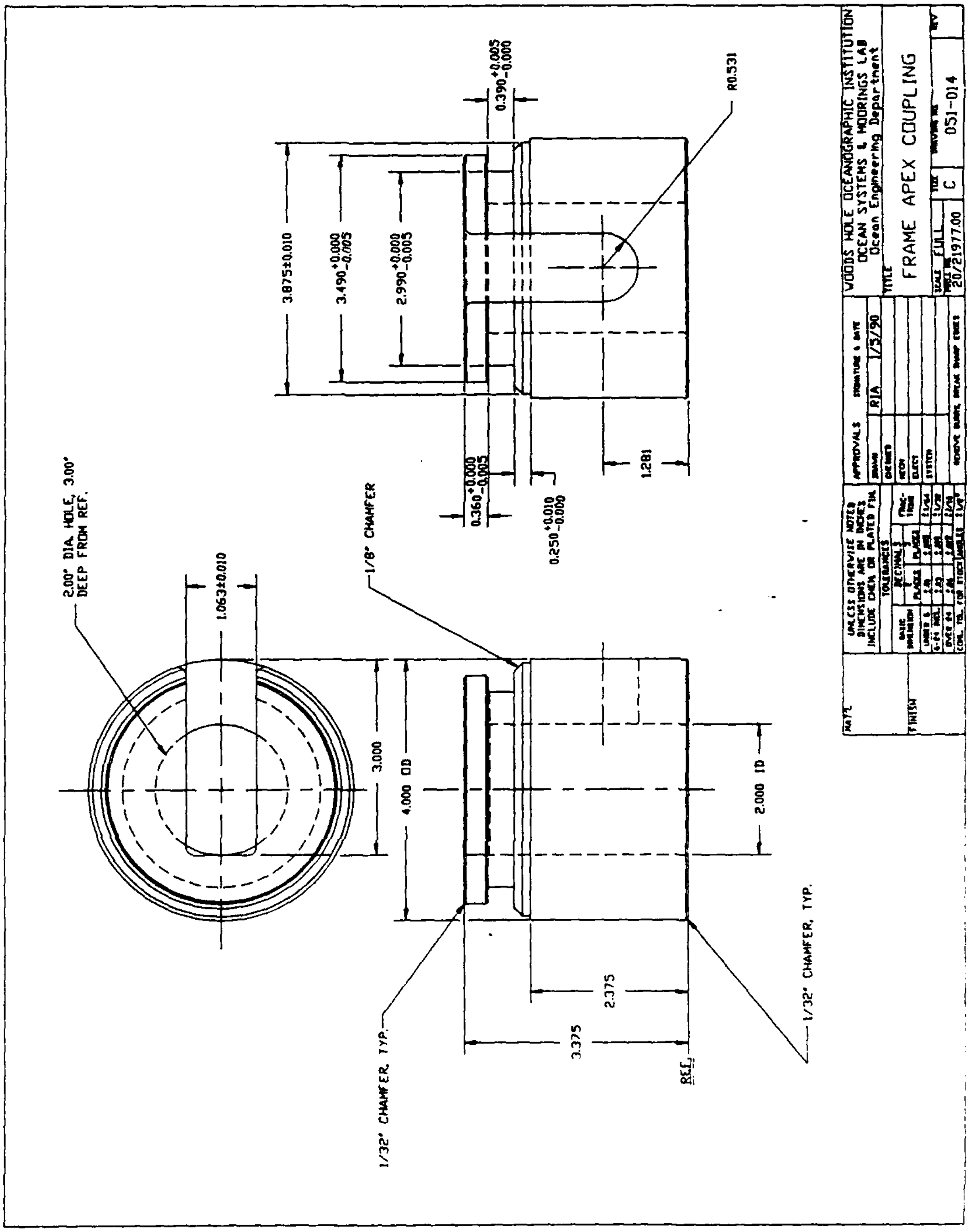

WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept.
TITLE
CLEVIS/LOAD CELL BOLT
SIZE C
DRAWING NO. 051-020
APPROVALS
SIGNATURE & DATE
DRAWN RIA 10/30/89
CHECKED
MECH
ELECT
SYSTEM
UNLESS OTHERWISE NOTED
DIMENSIONS ARE IN INCHES
INCLUDE CHEM OR PLATED FIN.
TOLERANCES
DECIMALS
FRAC-TIONS
QUANTITY
MAT'L
FINISH
REMOVE BURRS BREAK SHARP EDGES
1"-8 THD
1.500
1.000 DIA.
1/4" RAD. TYP
8.750
1.000 DIA. HOLE
2.500
1.000
0.500
0.500
0.500
0.938
1.875
1.000±0.005
THIS DRAWING IS PROPRIETARY AND IS THE PROPERTY OF WOODS HOLE OCEANOGRAPHIC INSTITUTION. THE DRAWING OR ANY PART THEREOF MUST NOT BE COPIED OR OTHERWISE REPRODUCED OR DIVULGED TO ANY OTHER PARTY OR USED FOR MANUFACTURE OR OTHER PURPOSES WITHOUT THE EXPRESS WRITTEN PERMISSION OF THE WOODS HOLE OCEANOGRAPHIC INSTITUTION.

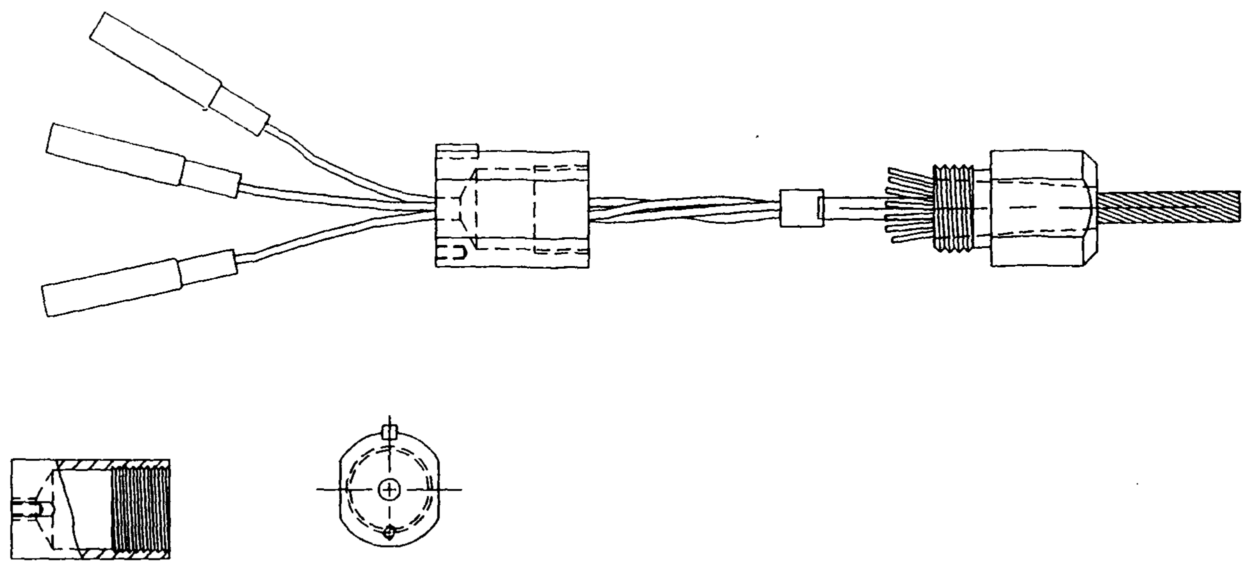

WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
COLLAR, TERMINATION
D
052-003
QUANTITY:
9/16" (.563) DRILL THRU
2 PLACES.
1/4" DIA X 1/2" LONG PINS
180 DEG APART ON A 5.50"
DIA BC. 2 PLACES
9/16" (.563) DRILL THRU
C'BORE TO .500 FROM REF.
2 PLACES
NOTE:
A .109 FROM CENTER LINE, INCLUDES SAW CUT
AND CLEAN UP MILLING OPERATION
REF.
4.000 OD
6.000
7.000
7.500
9.500
1.000
0.625
0.500
0.406
0.109
0.750
2.000
15°
45°



5/16' DRILL, THRU AND TAP 3/8-16 THD. EQUALLY SPACED ON A 3.940 IN. DIA. B.C. 6 PLACES.
3.000 I.D.
6.000 O.D.
1/16' CHAMFER, TYP.
0.500
QUANTITY:
MAT'L
FINISH
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM OR PLATED FIN.
TOLERANCES
APPROVALS
R/A 1/12/90
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
TITLE
PLATE, APEX COUPLING
SCALE FULL
C
051-012
20/21977.00


1/8" RAD. TYP.
1/8" CHAMFER
1/8" RAD.TYP.
6.000 O.D.
5.000
3.900 I.D.
1.063
0.250
9/32" (0.281) MILLED SLOT,
2 PLACES.
QUANTITY: 1 PIECE
MAT'L
FINISH
UNLESS OTHERWISE NOTED
DIMENSIONS ARE IN INCHES
INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
DECIMALS
APPROVALS
SIGNATURE & DATE
DRAWN
RIA 1/12/90
CHECKED
MECH
ELECT
SYSTEM
REMOVE BURRS, BREAK SHARP EDGES
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
TITLE
RING, APEX COUPLING
SCALE FULL
SIZE
C
DRAWING NO
051-013
REV
20/21977.00


WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
TITLE
FRAME APEX COUPLING
SCALE FULL
20/21977.00
SIZE C
051-014
REV
APPROVALS
SIGNATURE & DATE
RIA 1/5/90
FINISH
MAT'L
2.00" DIA. HOLE, 3.00" DEEP FROM REF.
1.063±0.010
1/8" CHAMFER
3.000
4.000 OD
2.000 ID
1/32" CHAMFER, TYP.
1/32" CHAMFER, TYP.
2.375
3.375
REF.
3.875±0.010
3.490+0.000 −0.005
2.990+0.000 −0.005
0.390+0.005 −0.000
R0.531
0.360+0.000 −0.005
0.250+0.010 −0.000
1.281



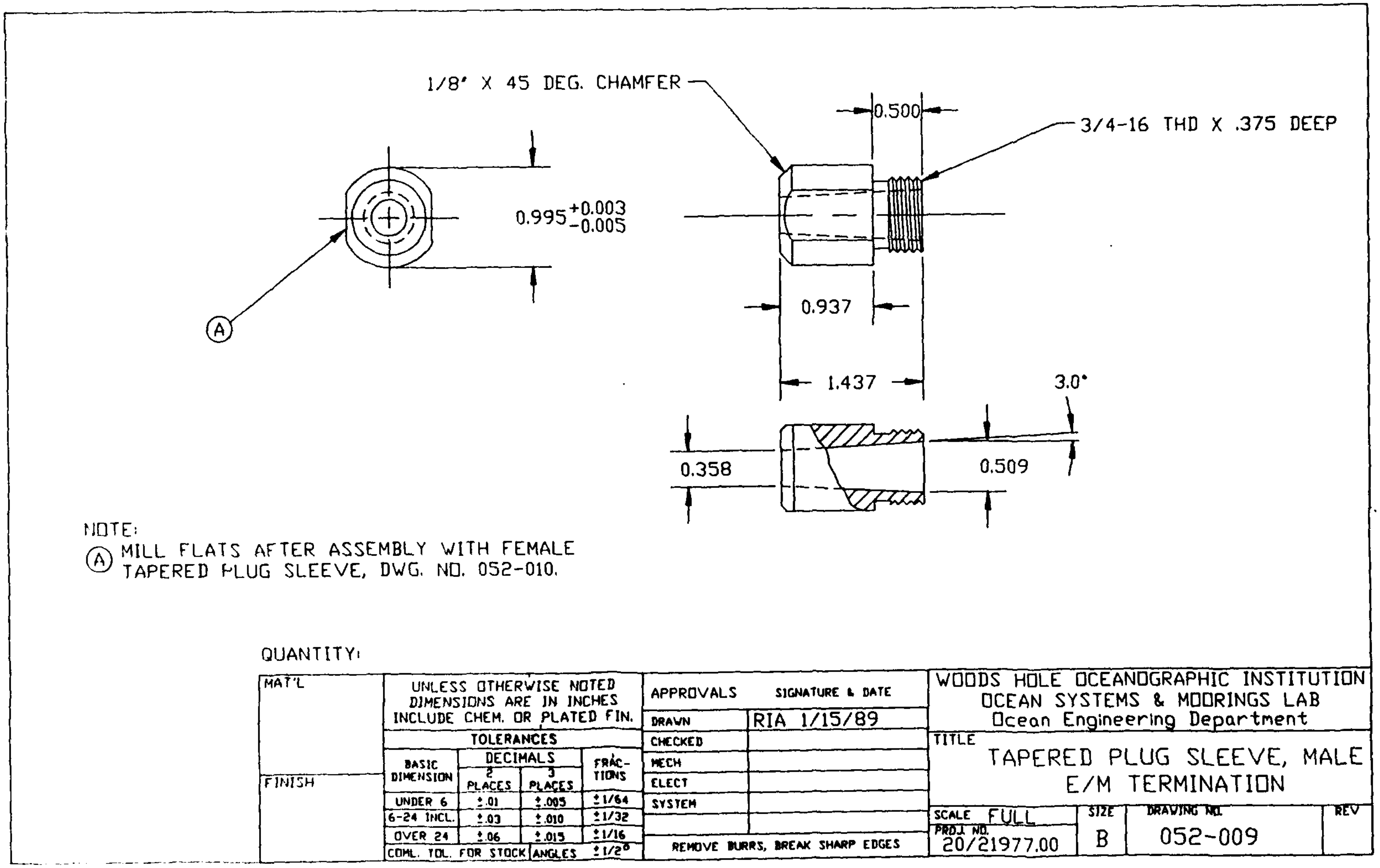
QUANTITY:

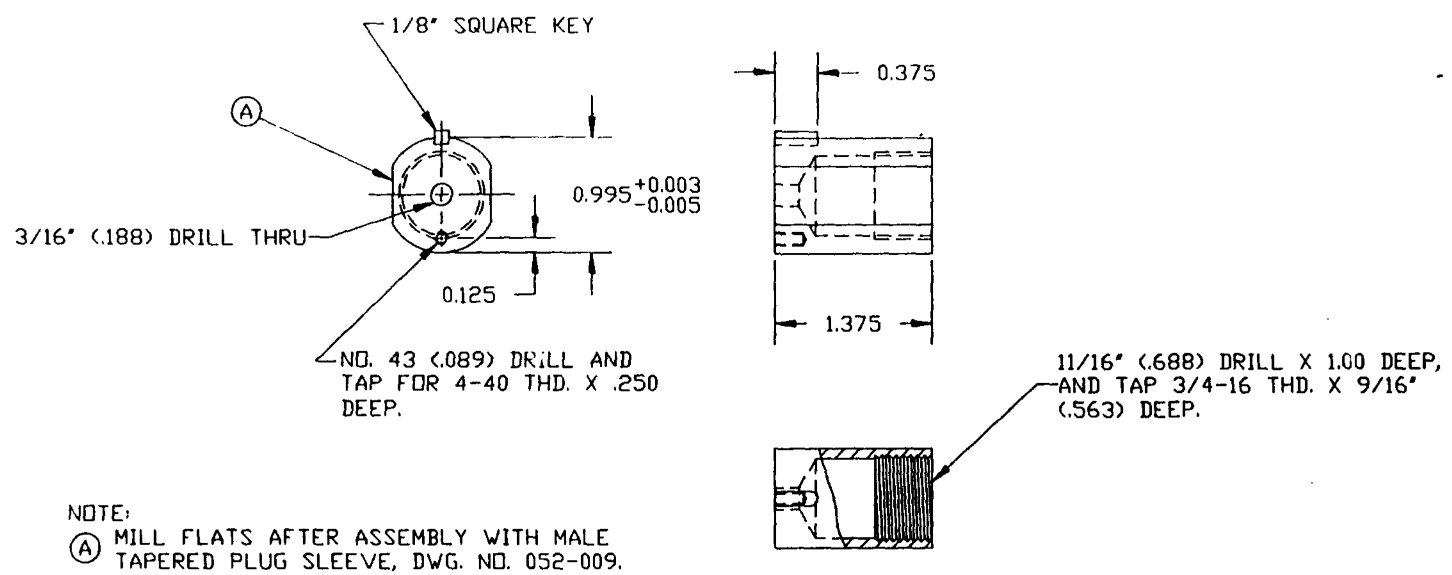
MAT'L	UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.				APPROVALS	SIGNATURE & DATE
	TOLERANCES				DRAWN	RIA 1/15/89
	BASIC DIMENSION	DECIMALS 2 PLACES	DECIMALS 3 PLACES	FRAC-TIONS	CHECKED	
FINISH	UNDER 6	±.01	±.005	±1/64	MECH	
	6-24 INCL.	±.03	±.010	±1/32	ELECT	
	OVER 24	±.06	±.015	±1/16	SYSTEM	
	COML. TOL. FOR STOCK	ANGLES		±1/2°	REMOVE BURRS, BREAK SHARP EDGES	

WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department

TITLE

SCALE FULL / PROJ. NO.	SIZE	DRAWING NO.	REV
20/21977.00	B	052-011	

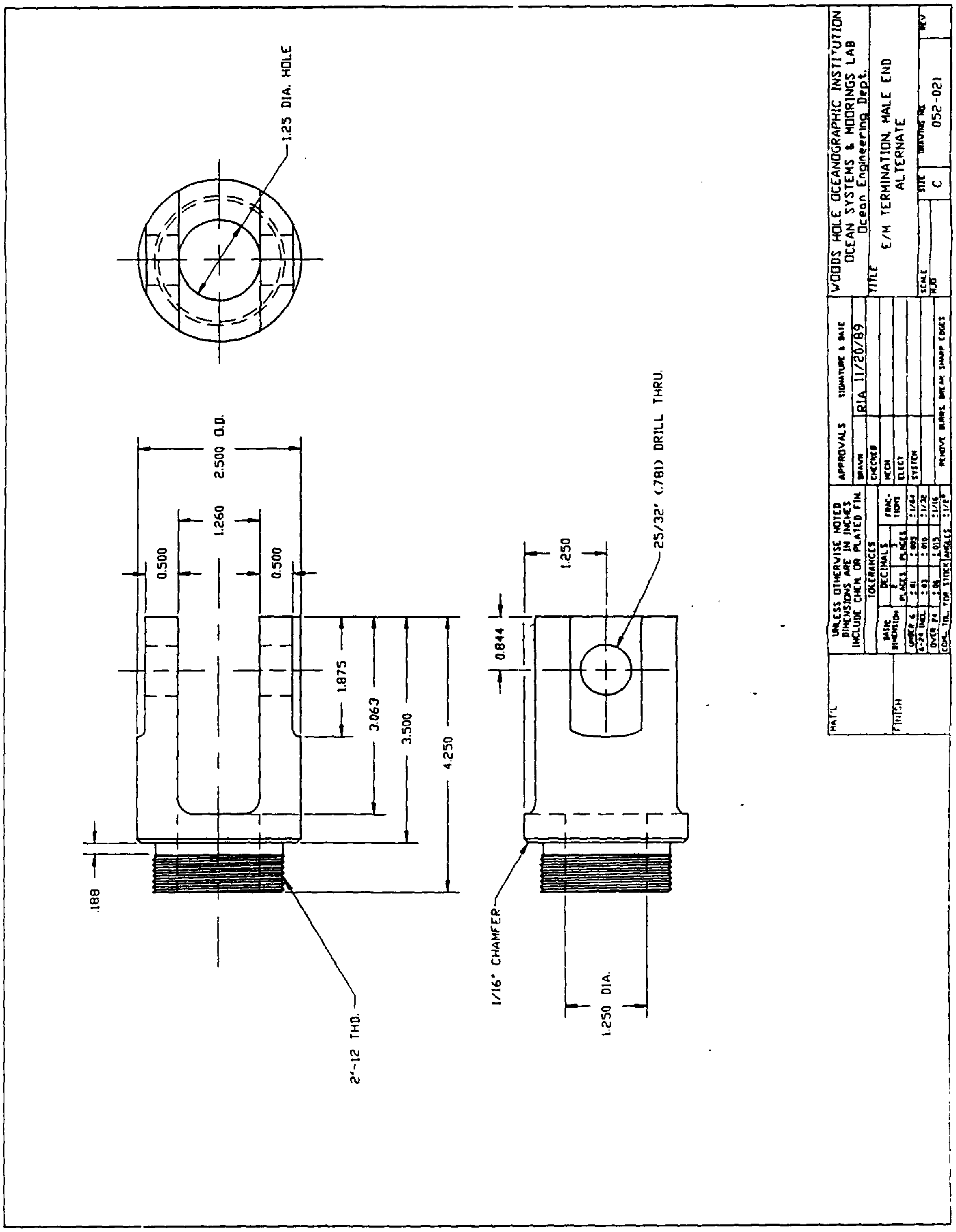

1/8' X 45 DEG. CHAMFER
0.500
3/4-16 THD X .375 DEEP
0.995 +0.003 -0.005
A
0.937
1.437
3.0°
0.358
0.509
NOTE:
A MILL FLATS AFTER ASSEMBLY WITH FEMALE TAPERED PLUG SLEEVE, DWG. NO. 052-010.
QUANTITY:
MAT'L
FINISH
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
BASIC DIMENSION
DECIMALS
2 PLACES
3 PLACES
FRAC-TIONS
UNDER 6 ±.01 ±.005 ±1/64
6-24 INCL. ±.03 ±.010 ±1/32
OVER 24 ±.06 ±.015 ±1/16
COML. TOL. FOR STOCK ANGLES ±1/2°
APPROVALS
SIGNATURE & DATE
DRAWN RIA 1/15/89
CHECKED
MECH
ELECT
SYSTEM
REMOVE BURRS, BREAK SHARP EDGES
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
TITLE
TAPERED PLUG SLEEVE, MALE
E/M TERMINATION
SCALE FULL
PROJ. NO. 20/21977.00
SIZE B
DRAWING NO. 052-009
REV

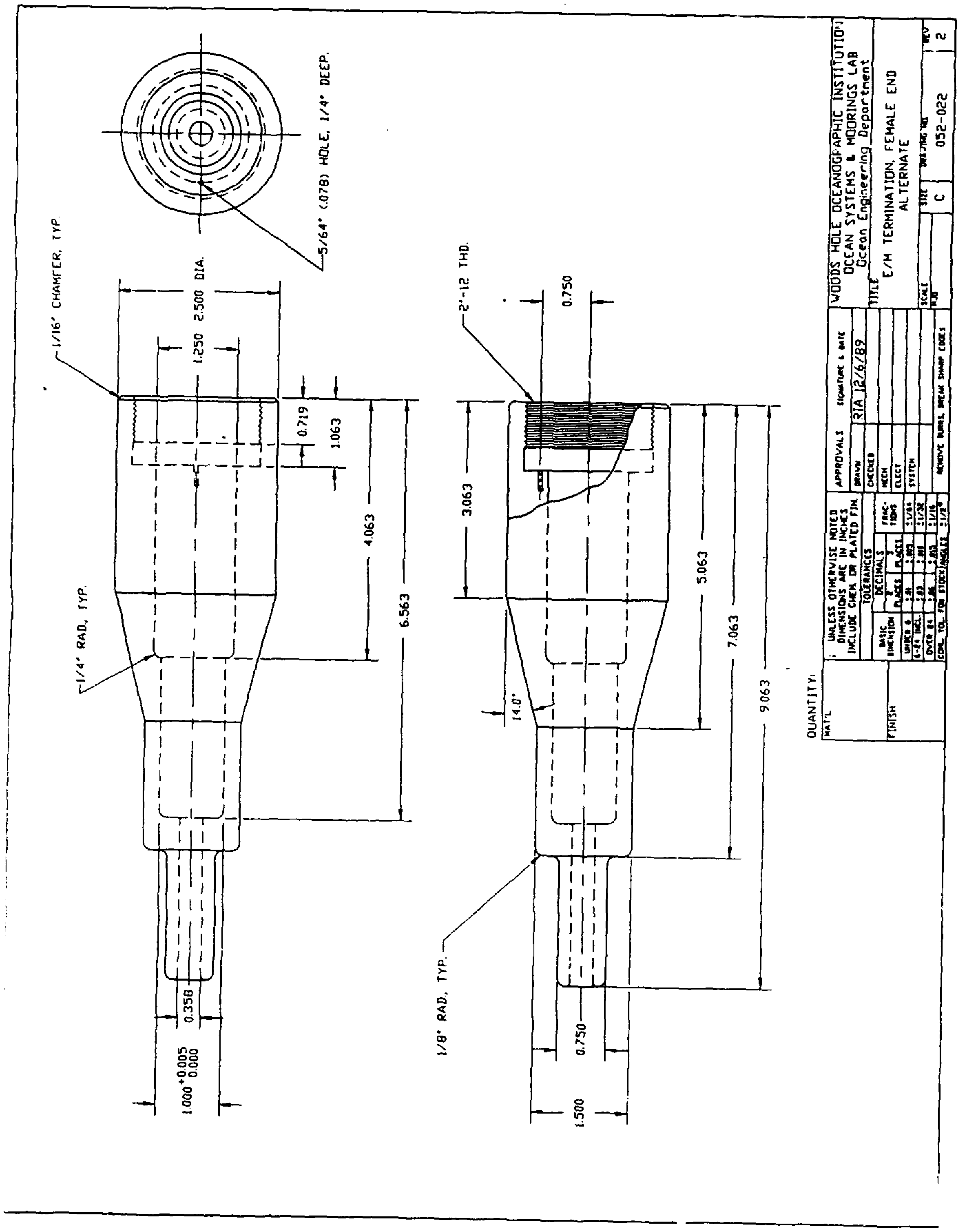


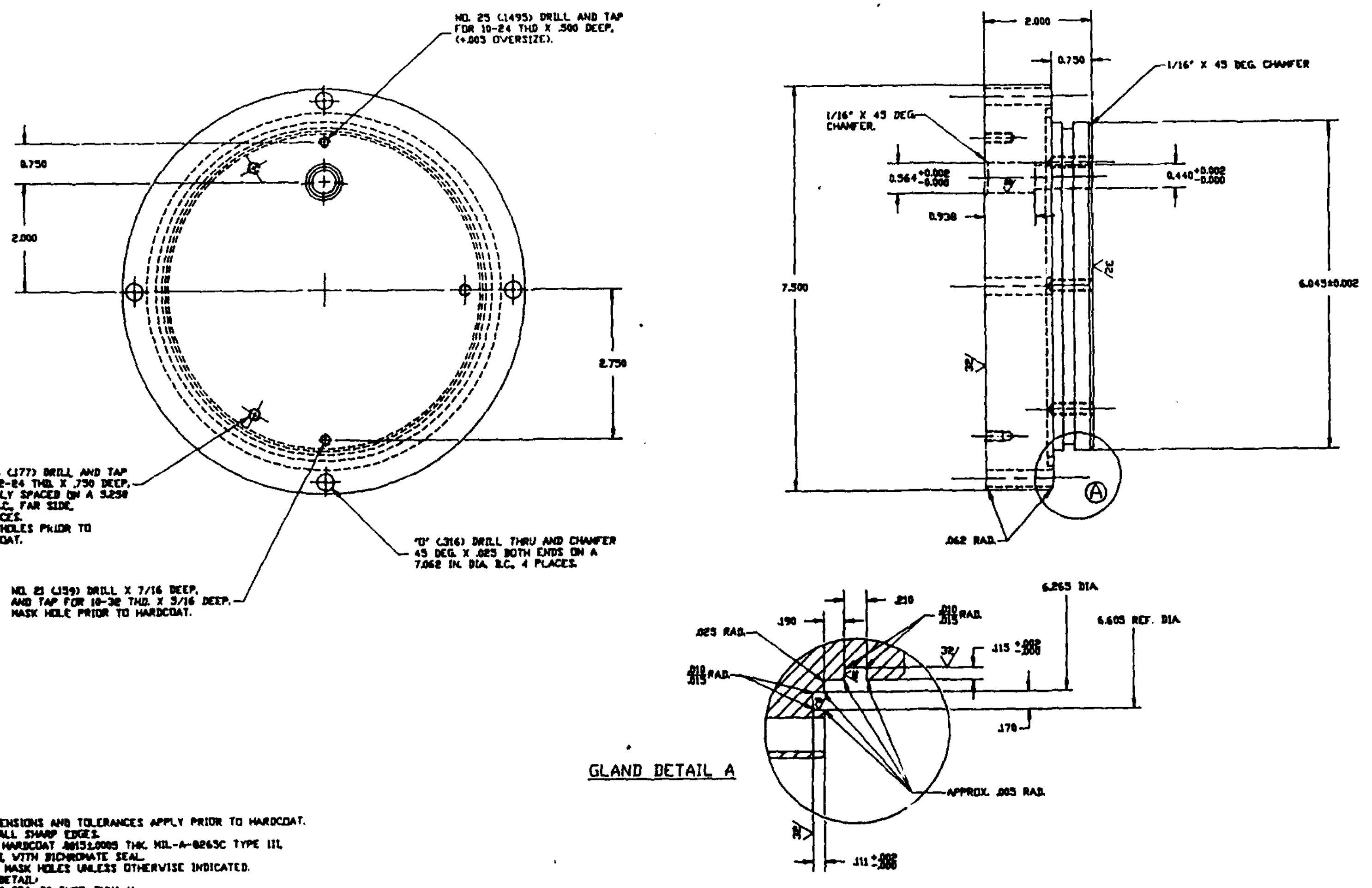
NOTE:
(A) MILL FLATS AFTER ASSEMBLY WITH MALE TAPERED PLUG SLEEVE, DWG. NO. 052-009.

QUANTITY:

MAT'L	UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.				APPROVALS	SIGNATURE & DATE	WOODS HOLE OCEANOGRAPHIC INSTITUTION OCEAN SYSTEMS & MOORINGS LAB Ocean Engineering Department
	TOLERANCES				DRAWN	RIA 1/15/89	
	BASIC DIMENSION	DECIMALS 2 PLACES	DECIMALS 3 PLACES	FRAC-TIONS	CHECKED		TITLE TAPERED PLUG SLEEVE, FEMALE E/M TERMINATION
FINISH	UNDER 6	±.01	±.005	±1/64	MECH		
	6-24 INCL.	±.03	±.010	±1/32	ELECT		SCALE FULL
	OVER 24	±.06	±.015	±1/16	SYSTEM		PROJ. NO. 20/21977.00 · SIZE B · DRAWING NO. 052-010 · REV
	COML. TOL. FOR STOCK		ANGLES	±1/2°	REMOVE BURRS, BREAK SHARP EDGES		


1.25 DIA. HOLE
2.500 O.D.
1.260
0.500
0.500
1.875
3.063
3.500
4.250
.188
2"-12 THD.
25/32" (.781) DRILL THRU.
1.250
0.844
1/16" CHAMFER
1.250 DIA.
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
APPROVALS
SIGNATURE & DATE
DRAWN
RIA 11/20/89
CHECKED
MECH
ELECT
SYSTEM
REMOVE BURRS, BREAK SHARP EDGES
MAT'L
FINISH
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept.
TITLE
E/M TERMINATION, MALE END
ALTERNATE
SCALE
SIZE
C
DRAWING NO.
052-021
REV

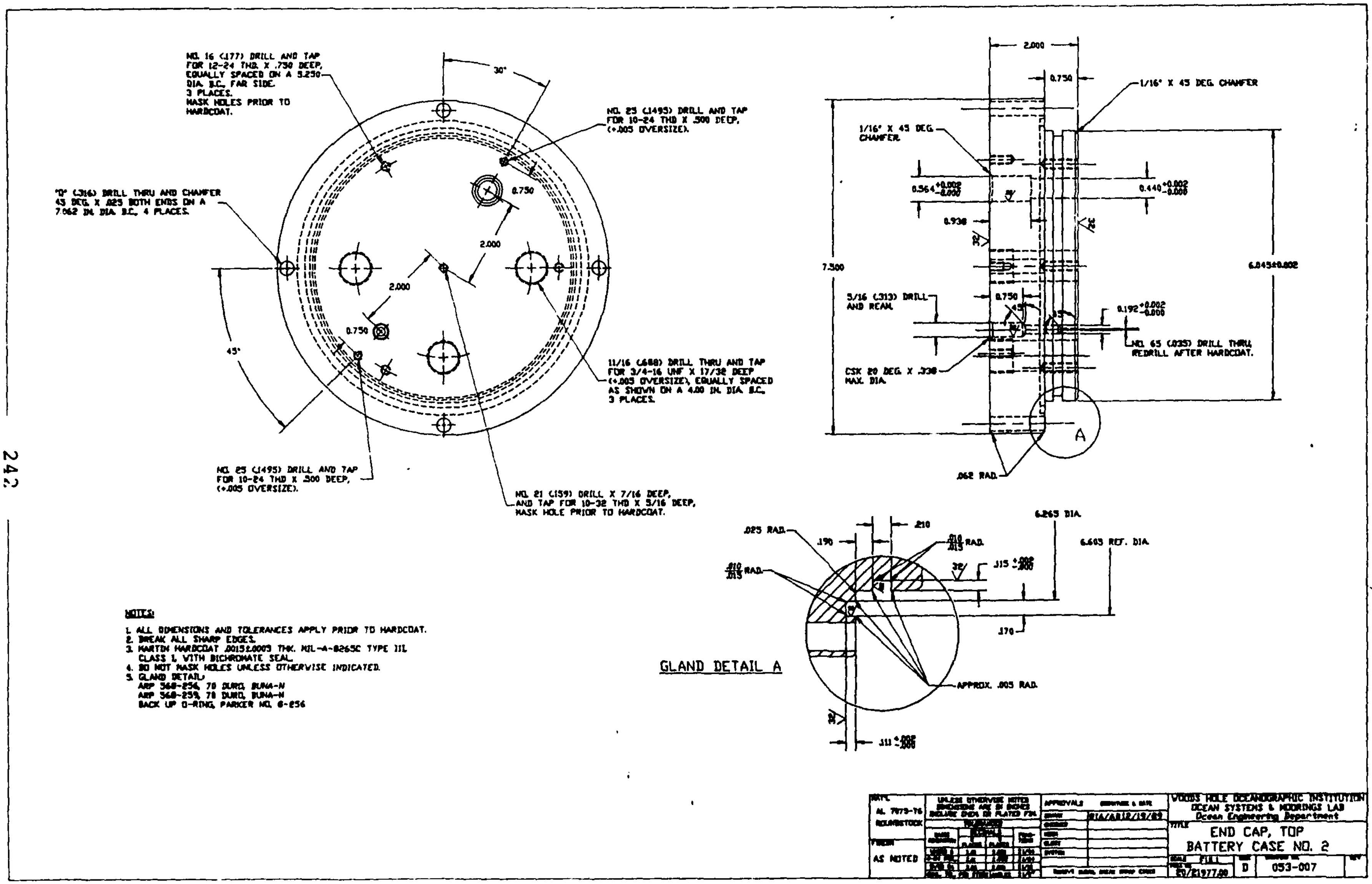

WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
TITLE
E/M TERMINATION, FEMALE END
ALTERNATE
SIZE
C
052-022
REV
2
SCALE
APPROVALS
DRAWN
RIA 12/6/89
CHECKED
MECH
ELECT
SYSTEM
REMOVE BURRS, BREAK SHARP EDGES
UNLESS OTHERWISE NOTED
DIMENSIONS ARE IN INCHES
INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
DECIMALS
FRACTIONS
QUANTITY:
MAT'L
FINISH
1/16" CHAMFER, TYP.
2.500 DIA.
1.250
5/64" (.078) HOLE, 1/4" DEEP.
0.719
1.063
4.063
6.563
1/4" RAD., TYP.
0.358
1.000 +0.005 0.000
2"-12 THD.
0.750
3.063
5.063
7.063
9.063
14.0°
1/8" RAD., TYP.
0.750
1.500

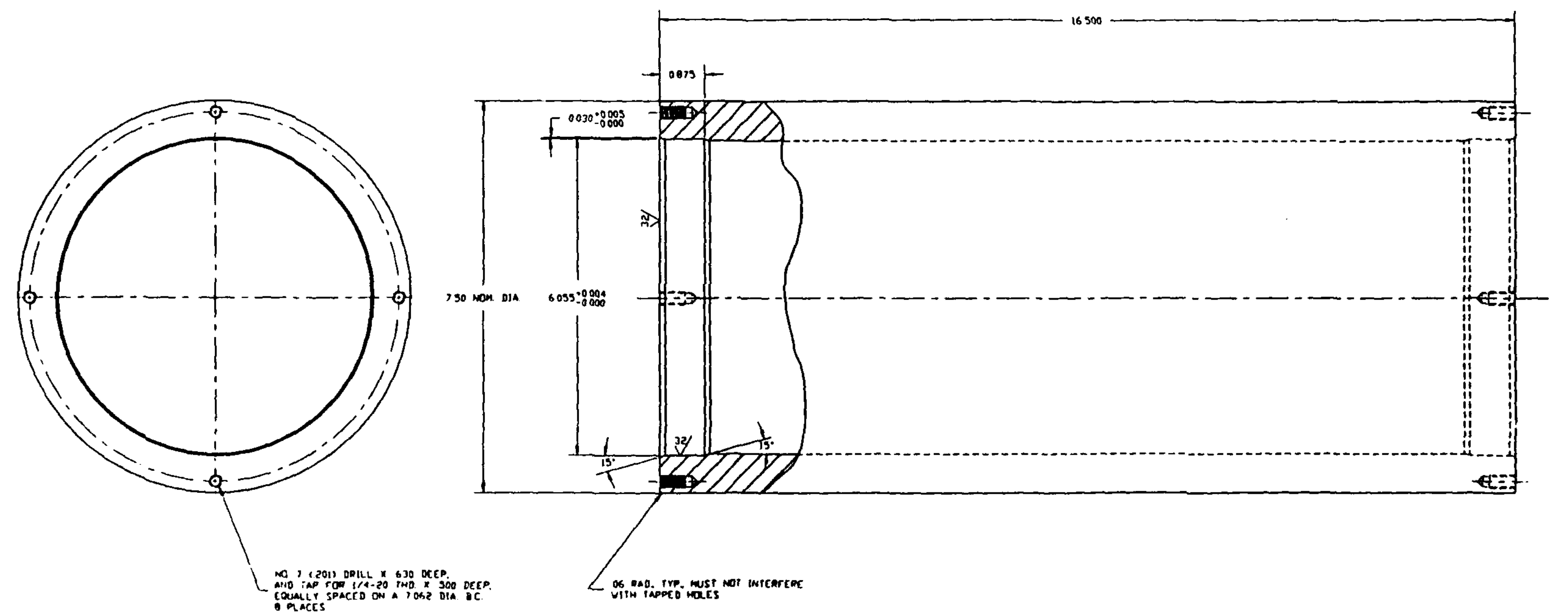


NOTES:

1. ALL DIMENSIONS AND TOLERANCES APPLY PRIOR TO HARDCOAT.
2. BREAK ALL SHARP EDGES.
3. MARTIN HARDCOAT .0015±.0005 THK. MIL-A-8263C TYPE III, CLASS 1, WITH BICHROMATE SEAL.
4. DO NOT MASK HOLES UNLESS OTHERWISE INDICATED.
5. GLAND DETAIL:
   ARP 568-256, 70 DURO. BUNA-N
   ARP 568-239, 70 DURO. BUNA-N
   BACK UP O-RING, PARKER NO. 8-256

MAT'L	AL 7075-T6 ROUNDSTOCK
FINISH	AS NOTED
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES	
APPROVALS	DRAWN BIA/AB 12/18/89
WOODS HOLE OCEANOGRAPHIC INSTITUTION	OCEAN SYSTEMS & MOORINGS LAB, Ocean Engineering Department
TITLE	END CAP, BOTTOM BATTERY CASE
SCALE	FULL
SIZE	D
DRAWING NO.	053-006


NO. 16 (.177) DRILL AND TAP FOR 12-24 THD. X .750 DEEP, EQUALLY SPACED ON A 5.250 DIA. B.C., FAR SIDE. 3 PLACES. MASK HOLES PRIOR TO HARDCOAT.
30°
NO. 25 (.1495) DRILL AND TAP FOR 10-24 THD X .500 DEEP, (+.005 OVERSIZE).
"O" (.316) DRILL THRU AND CHAMFER 45 DEG. X .025 BOTH ENDS ON A 7.062 IN. DIA. B.C., 4 PLACES.
0.750
2.000
2.000
0.750
45°
11/16 (.688) DRILL THRU AND TAP FOR 3/4-16 UNF X 17/32 DEEP (+.005 OVERSIZE), EQUALLY SPACED AS SHOWN ON A 4.00 IN. DIA. B.C. 3 PLACES.
NO. 25 (.1495) DRILL AND TAP FOR 10-24 THD X .500 DEEP, (+.005 OVERSIZE).
NO. 21 (.159) DRILL X 7/16 DEEP, AND TAP FOR 10-32 THD X 5/16 DEEP, MASK HOLE PRIOR TO HARDCOAT.
2.000
0.750
1/16" X 45 DEG. CHAMFER
1/16" X 45 DEG. CHAMFER
0.564 +0.002 -0.000
0.440 +0.002 -0.000
0.938
7.500
6.845±0.002
5/16 (.313) DRILL AND REAM.
0.750
0.192 +0.002 -0.000
NO. 65 (.035) DRILL THRU REDRILL AFTER HARDCOAT.
CSK 20 DEG. X .330 MAX. DIA.
A
.062 RAD.
.025 RAD.
.190
.210
6.265 DIA.
.010 .015 RAD.
.010 .015 RAD.
6.603 REF. DIA.
.315 +.002 -.000
.170
APPROX. .005 RAD.
.311 +.002 -.000
GLAND DETAIL A
NOTES:
1. ALL DIMENSIONS AND TOLERANCES APPLY PRIOR TO HARDCOAT.
2. BREAK ALL SHARP EDGES.
3. MARTIN HARDCOAT .0015±.0005 THK. MIL-A-8625C TYPE III CLASS 1, WITH BICHROMATE SEAL.
4. DO NOT MASK HOLES UNLESS OTHERWISE INDICATED.
5. GLAND DETAIL:
ARP 568-256, 70 DURO, BUNA-N
ARP 568-259, 70 DURO, BUNA-N
BACK UP O-RING, PARKER NO. 8-256
AL 7075-T6
ROUNDSTOCK
AS NOTED
UNLESS OTHERWISE NOTED
APPROVALS
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
END CAP, TOP
BATTERY CASE NO. 2
D
053-007



NOTES:

1 FABRICATE FOUR CASES, SAME LENGTH
2 DIMENSIONS AND TOLERANCES APPLY PRIOR TO HARDCOATING
3 BREAK ALL SHARP EDGES
4 PAPER POLISH O.D. OF TUBE FOR SMOOTH FINISH
5 MARTIN HARDCOAT .0015 ± .0005 THK. PER MIL-A-8625C, TYPE III, CLASS I, WITH DICHROMATE SEAL. CONTACT POINTS FOR HARDCOAT MUST BE ON I.D. OF TUBE, CLEAR OF MACHINED ENDS

MASK ALL HOLES PRIOR TO HARDCOAT

MAT'L AL 7075-T6 7.50 O.D. .750 WALL

FINISH AS NOTED

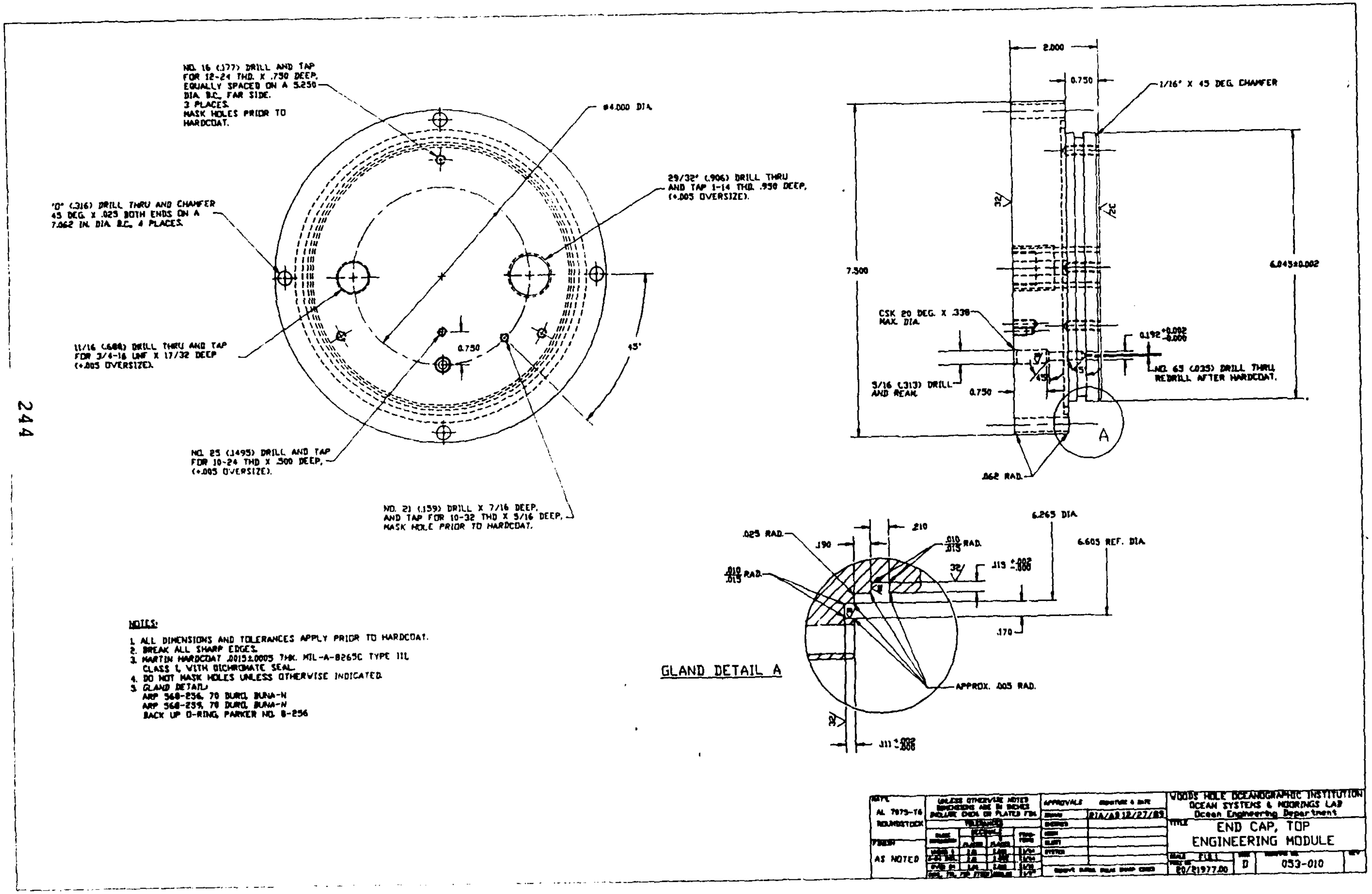
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM OR PLATED FIN.

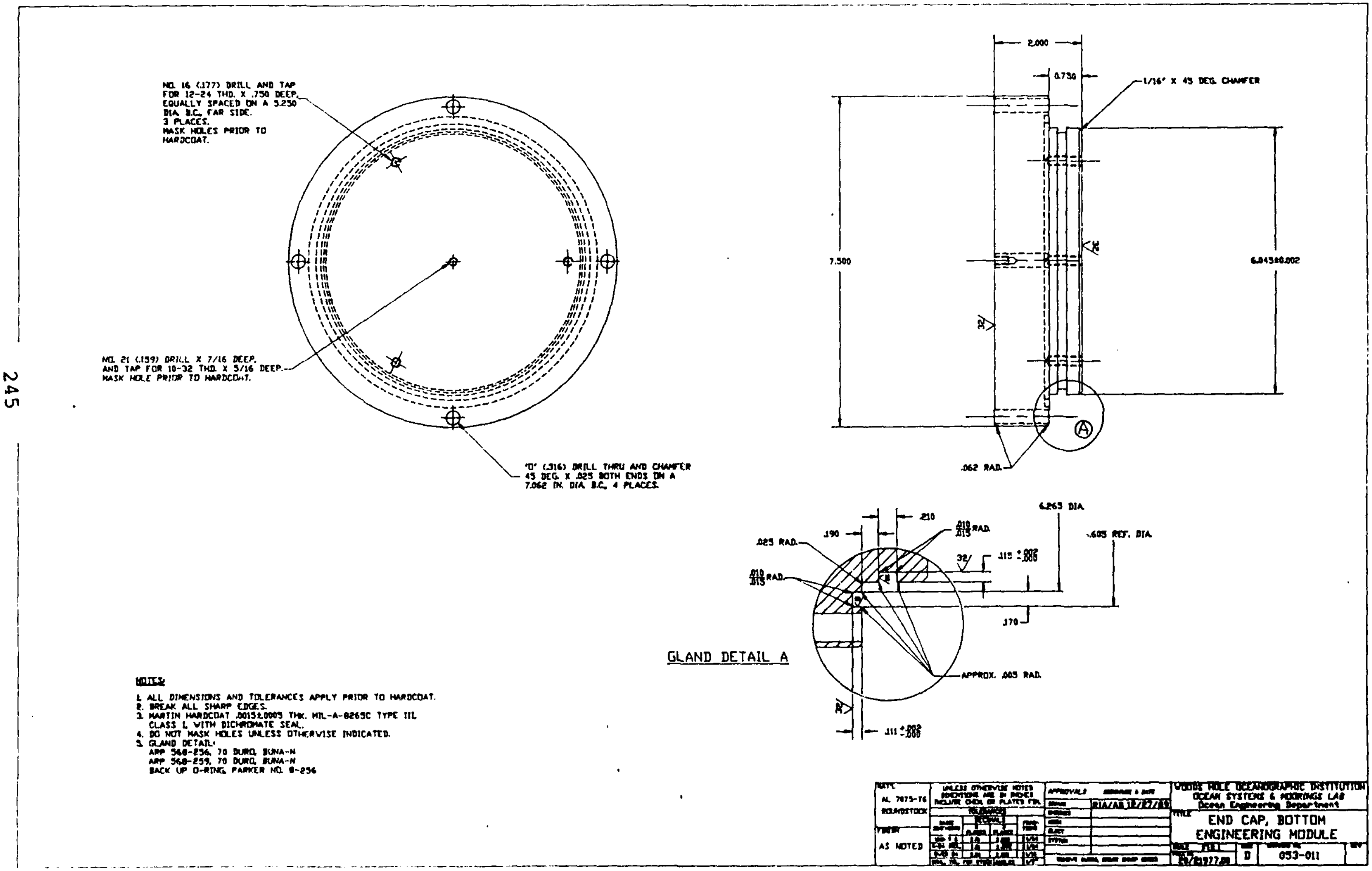
DRAWN RIA/AB 12/12/89

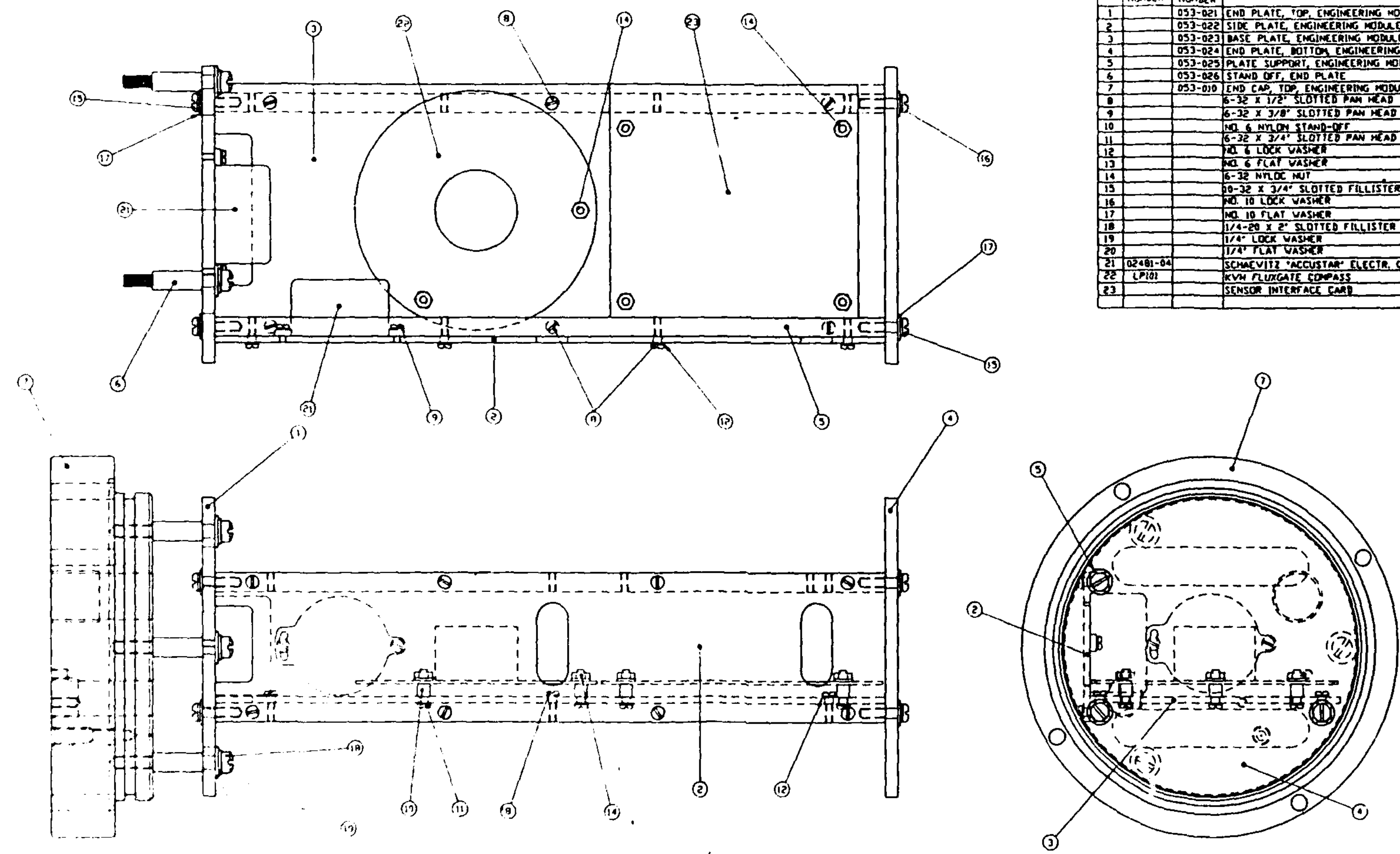
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department

TITLE PRESSURE CYLINDER WATER SAMPLER

20/21977.00 | D | 053-004


NO. 16 (.177) DRILL AND TAP FOR 12-24 THD. X .750 DEEP, EQUALLY SPACED ON A 5.250 DIA B.C., FAR SIDE. 3 PLACES. MASK HOLES PRIOR TO HARDCOAT.
ø4.000 DIA.
"O" (.316) DRILL THRU AND CHAMFER 45 DEG. X .025 BOTH ENDS ON A 7.062 IN. DIA. B.C., 4 PLACES.
29/32" (.906) DRILL THRU AND TAP 1-14 THD. .950 DEEP, (+.005 OVERSIZE).
11/16 (.688) DRILL THRU AND TAP FOR 3/4-16 UNF X 17/32 DEEP (+.005 OVERSIZE).
0.750
45°
NO. 25 (.1495) DRILL AND TAP FOR 10-24 THD X .500 DEEP, (+.005 OVERSIZE).
NO. 21 (.159) DRILL X 7/16 DEEP, AND TAP FOR 10-32 THD X 5/16 DEEP, MASK HOLE PRIOR TO HARDCOAT.
2.000
0.750
1/16" X 45 DEG. CHAMFER
7.500
6.045±0.002
CSK 20 DEG. X .338 MAX. DIA.
0.192 +0.002 -0.000
5/16 (.313) DRILL AND REAM.
0.750
NO. 63 (.035) DRILL THRU REDRILL AFTER HARDCOAT.
.062 RAD.
A
6.265 DIA.
6.605 REF. DIA.
.025 RAD.
.190
.210
.010 .015 RAD.
.113 +.002 -.000
.170
APPROX. .005 RAD.
.111 +.002 -.000
GLAND DETAIL A
NOTES:
1. ALL DIMENSIONS AND TOLERANCES APPLY PRIOR TO HARDCOAT.
2. BREAK ALL SHARP EDGES.
3. MARTIN HARDCOAT .0015±.0005 THK. MIL-A-8625C TYPE III, CLASS 1, WITH DICHROMATE SEAL.
4. DO NOT MASK HOLES UNLESS OTHERWISE INDICATED.
5. GLAND DETAIL: ARP 568-256, 70 DURO. BUNA-N ARP 568-259, 70 DURO. BUNA-N BACK UP O-RING, PARKER NO. 8-256
AL 7075-T6 ROUNDSTOCK
AS NOTED
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
END CAP, TOP
ENGINEERING MODULE
FULL
D
053-010
20/21977.00


NO. 16 (.177) DRILL AND TAP FOR 12-24 THD. X .750 DEEP. EQUALLY SPACED ON A 5.250 DIA. B.C. FAR SIDE. 3 PLACES. MASK HOLES PRIOR TO HARDCOAT.
NO. 21 (.159) DRILL X 7/16 DEEP, AND TAP FOR 10-32 THD. X 5/16 DEEP. MASK HOLE PRIOR TO HARDCOAT.
"D" (.316) DRILL THRU AND CHAMFER 45 DEG. X .025 BOTH ENDS ON A 7.062 IN. DIA. B.C. 4 PLACES.
2.000
0.750
1/16" X 45 DEG. CHAMFER
7.500
6.845±0.002
32
A
.062 RAD.
GLAND DETAIL A
.025 RAD.
.190
.210
.010 .015 RAD.
6.265 DIA.
.605 REF. DIA.
.115 +.002 -.000
.370
APPROX. .005 RAD.
.111 +.002 -.000
NOTES:
1. ALL DIMENSIONS AND TOLERANCES APPLY PRIOR TO HARDCOAT.
2. BREAK ALL SHARP EDGES.
3. MARTIN HARDCOAT .0015±.0005 THK. MIL-A-8265C TYPE III, CLASS 1, WITH DICHROMATE SEAL.
4. DO NOT MASK HOLES UNLESS OTHERWISE INDICATED.
5. GLAND DETAIL:
ARP 568-256, 70 DURO. BUNA-N
ARP 568-259, 70 DURO. BUNA-N
BACK UP O-RING, PARKER NO. 8-256
MAT'L
AL. 7075-T6
ROUNDSTOCK
FINISH
AS NOTED
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
DECIMALS
APPROVALS
DIA/AB 12/27/89
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
TITLE
END CAP, BOTTOM
ENGINEERING MODULE
FULL
D
053-011



ITEM	IDENT. NUMBER	DRAWING NUMBER	DESCRIPTION	QTY
1		053-021	END PLATE, TOP, ENGINEERING MODULE	1
2		053-022	SIDE PLATE, ENGINEERING MODULE	1
3		053-023	BASE PLATE, ENGINEERING MODULE	1
4		053-024	END PLATE, BOTTOM, ENGINEERING MODULE	1
5		053-025	PLATE SUPPORT, ENGINEERING MODULE	3
6		053-026	STAND OFF, END PLATE	3
7		053-010	END CAP, TOP, ENGINEERING MODULE	1
8			6-32 X 1/2" SLOTTED PAN HEAD SCREW	16
9			6-32 X 3/8" SLOTTED PAN HEAD SCREW	2
10			NO. 6 NYLON STAND-OFF	6
11			6-32 X 3/4" SLOTTED PAN HEAD SCREW	6
12			NO. 6 LOCK WASHER	24
13			NO. 6 FLAT WASHER	6
14			6-32 NYLOC NUT	6
15			10-32 X 3/4" SLOTTED FILLISTER HEAD SCREW	6
16			NO. 10 LOCK WASHER	6
17			NO. 10 FLAT WASHER	6
18			1/4-20 X 2" SLOTTED FILLISTER HEAD SCREW	3
19			1/4" LOCK WASHER	3
20			1/4" FLAT WASHER	3
21	02481-04		SCHAEVITZ "ACCUSTAR" ELECTR. CLINOMETER	2
22	LP101		KVH FLUXGATE COMPASS	1
23			SENSOR INTERFACE CARD	1

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.

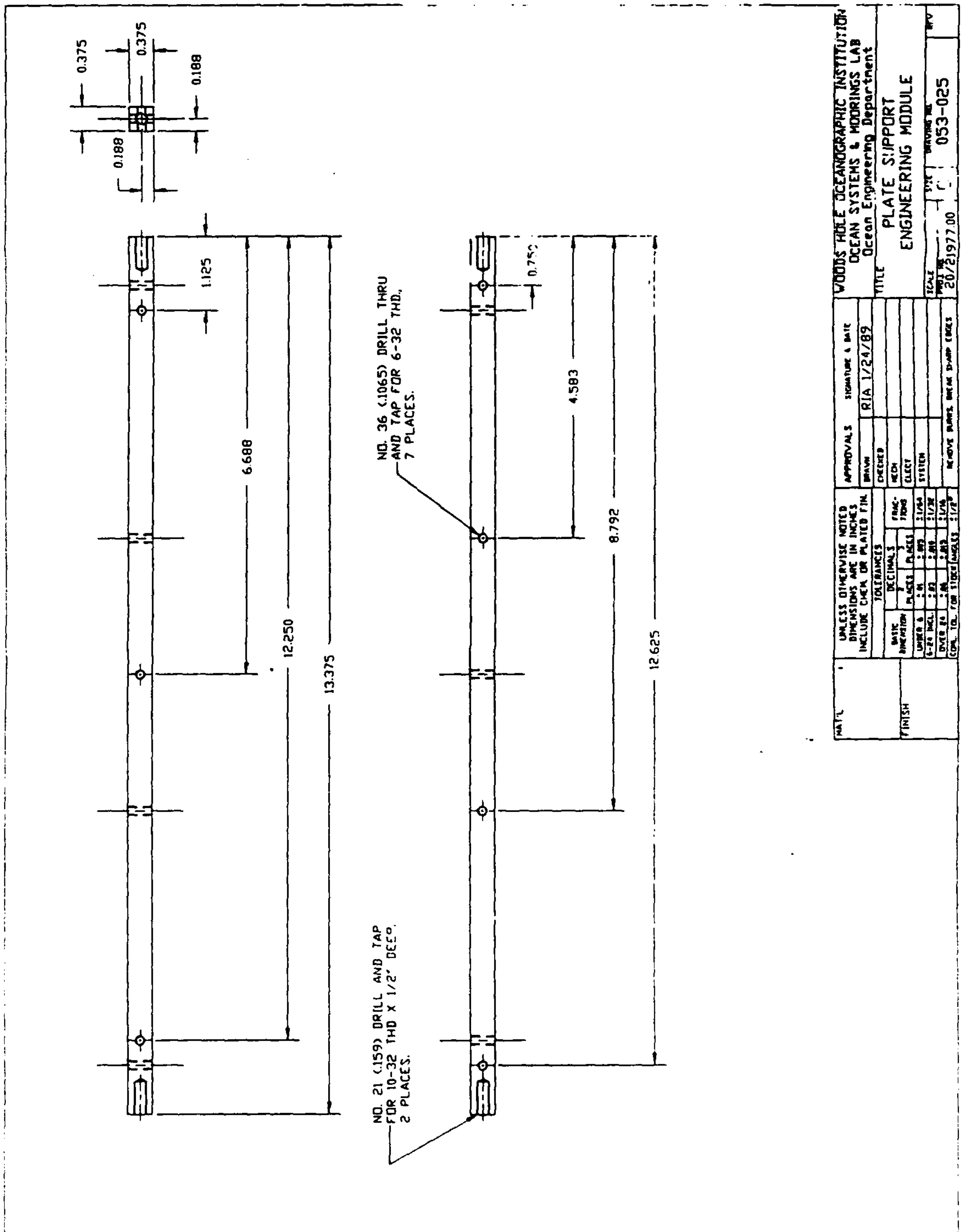
APPROVALS — SIGNATURE & DATE

DRAWN: RIA 1/27/90

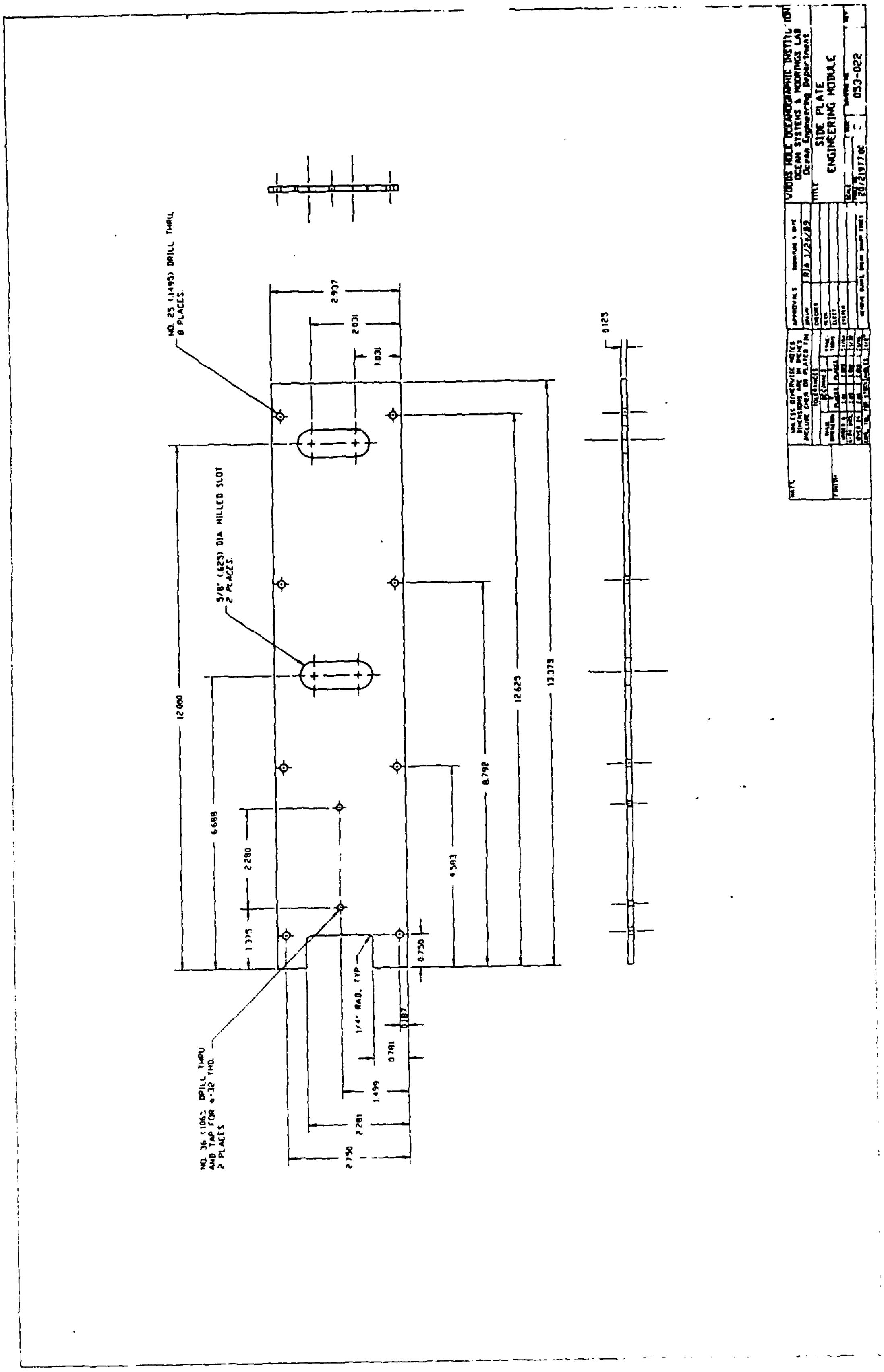
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department

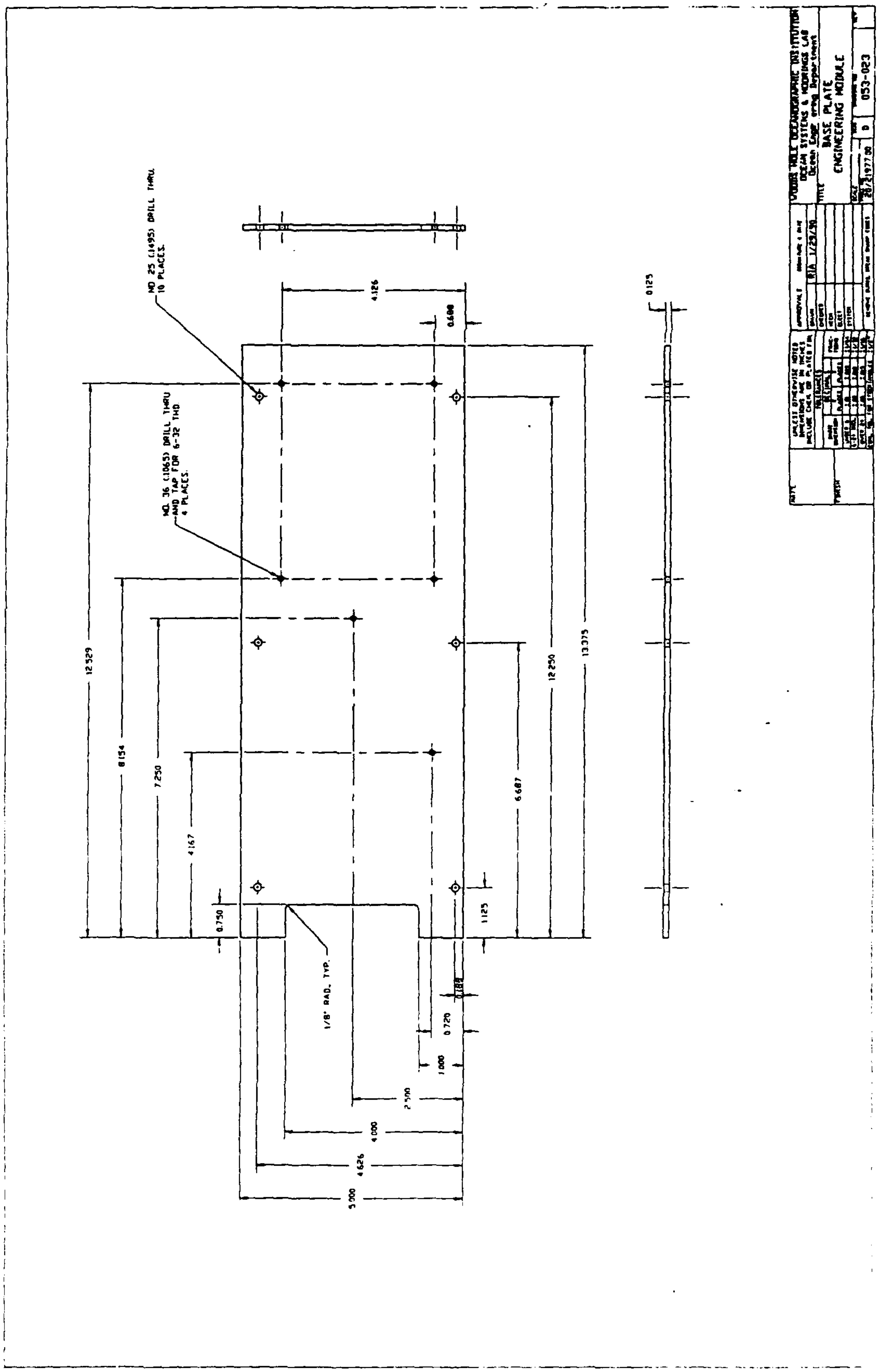
TITLE: ENGINEERING MODULE ASSEMBLY

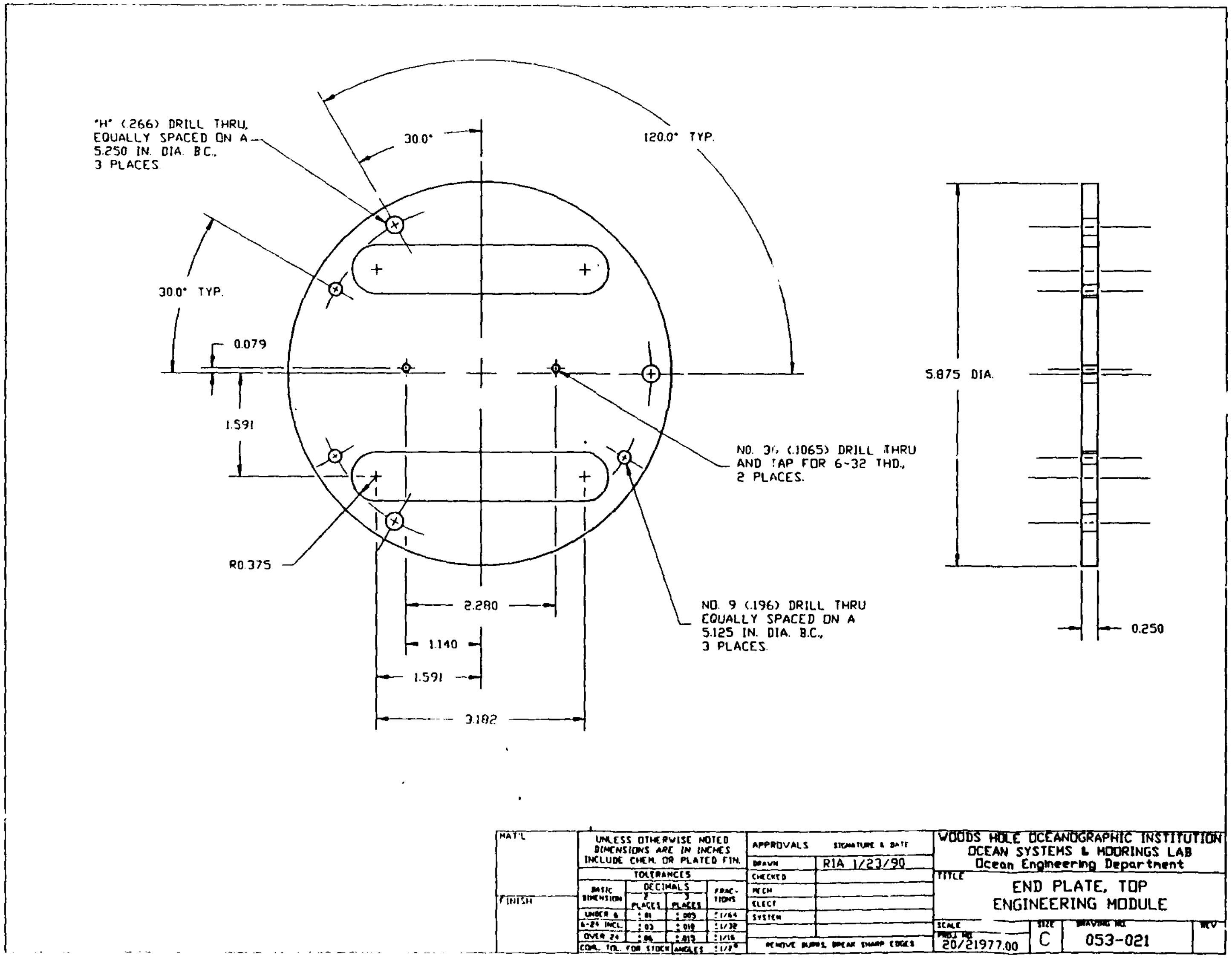
20/2197700 | SIZE D | DRAWING NO. 053-020

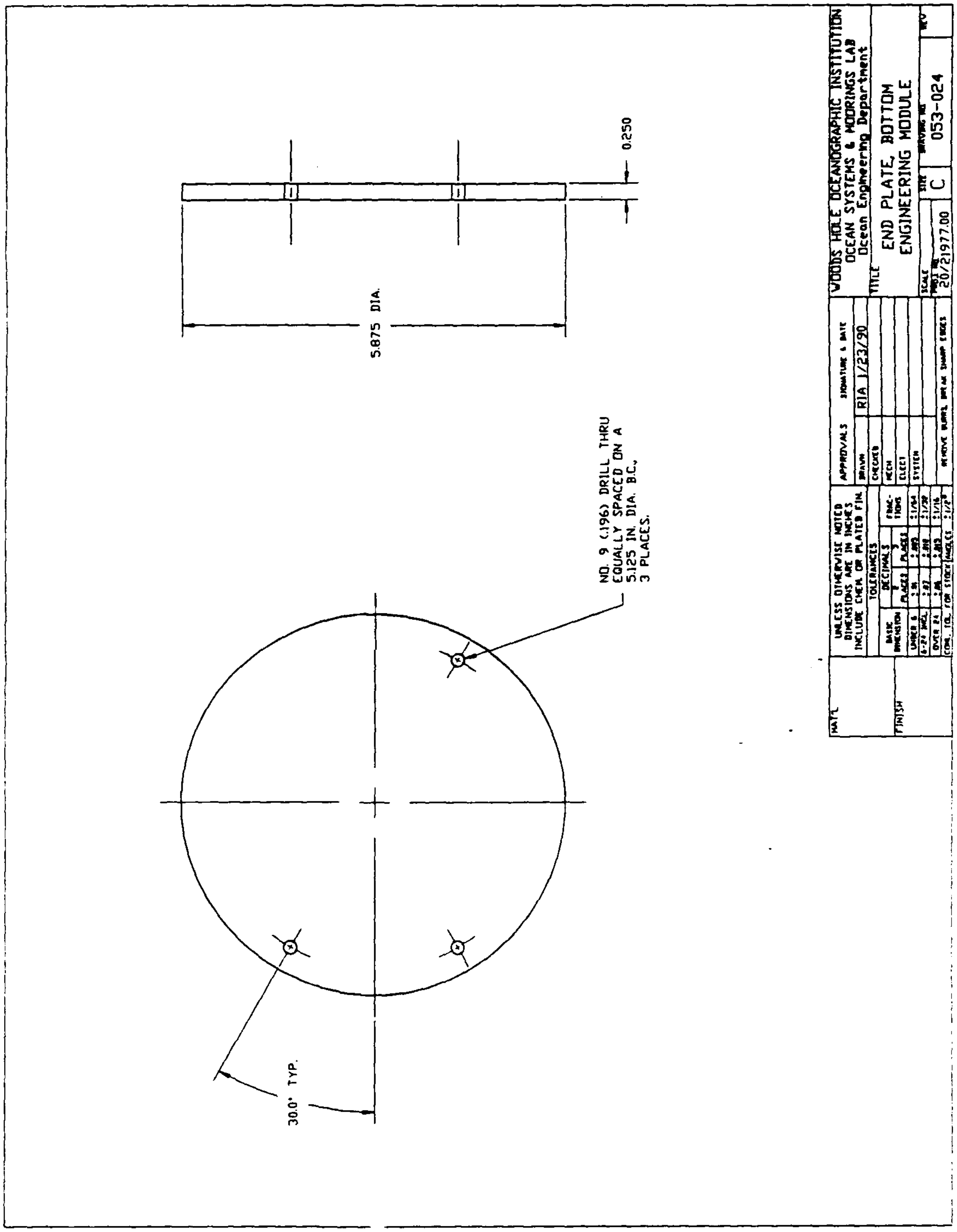


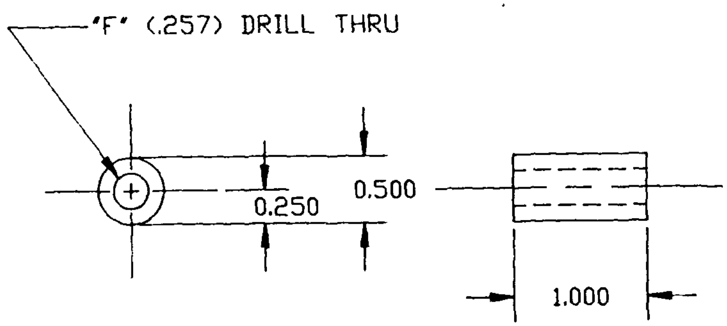
NO. 36 (.1065) DRILL THRU AND TAP FOR 6-32 THD, 7 PLACES.
NO. 21 (.159) DRILL AND TAP FOR 10-32 THD X 1/2" DEEP. 2 PLACES.
0.375
0.188
1.125
6.688
12.250
13.375
0.750
4.583
8.792
12.625
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
TITLE
PLATE SUPPORT
ENGINEERING MODULE
053-025
20/21977.00
RIA 1/24/89
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
APPROVALS
SIGNATURE & DATE
DRAWN
CHECKED
MECH
ELECT
SYSTEM
MAT'L
FINISH
REMOVE BURRS, BREAK SHARP EDGES


WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
SIDE PLATE
ENGINEERING MODULE
053-022
NO. 25 (.1495) DRILL THRU
8 PLACES
5/8" (.625) DIA MILLED SLOT
2 PLACES
NO. 36 (.1065) DRILL THRU
AND TAP FOR 6-32 THD.
2 PLACES
1/4" RAD. TYP


NO. 25 (.1495) DRILL THRU
10 PLACES.
NO. 36 (.1065) DRILL THRU
AND TAP FOR 6-32 THD
4 PLACES.
1/8" RAD. TYP.
4.126
0.600
0.125
12.529
8.154
7.250
4.167
0.750
1.125
6.687
12.250
13.375
0.720
1.000
2.500
4.000
4.626
5.000
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
BASE PLATE
ENGINEERING MODULE
053-023


"H" (266) DRILL THRU, EQUALLY SPACED ON A 5.250 IN. DIA. B.C., 3 PLACES
30.0°
120.0° TYP.
30.0° TYP.
0.079
1.591
R0.375
NO. 36 (.1065) DRILL THRU AND TAP FOR 6-32 THD., 2 PLACES.
NO. 9 (.196) DRILL THRU EQUALLY SPACED ON A 5.125 IN. DIA. B.C., 3 PLACES.
2.280
1.140
1.591
3.182
5.875 DIA.
0.250
MAT'L
FINISH
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
APPROVALS
SIGNATURE & DATE
DRAWN
RIA 1/23/90
CHECKED
MECH
ELECT
SYSTEM
REMOVE BURRS, BREAK SHARP EDGES
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
TITLE
END PLATE, TOP
ENGINEERING MODULE
SCALE
PROJ NO
20/21977.00
SIZE
C
DRAWING NO
053-021
REV


WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
END PLATE, BOTTOM
ENGINEERING MODULE
C
053-024
20/21977.00
RIA 1/23/90
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
APPROVALS
SIGNATURE & DATE
DRAWN
CHECKED
MECH
ELECT
SYSTEM
TITLE
SCALE
MAT'L
FINISH
NO. 9 (.196) DRILL THRU
EQUALLY SPACED ON A
5.125 IN. DIA. B.C.,
3 PLACES.
5.875 DIA.
0.250
30.0° TYP.



MAT'L: 6061-T6

FINISH

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.

TOLERANCES			
BASIC DIMENSION	DECIMALS 2 PLACES	DECIMALS 3 PLACES	FRACTIONS
UNDER 6	±.01	±.005	±1/64
6-24 INCL.	±.03	±.010	±1/32
OVER 24	±.06	±.015	±1/16
COML. TOL. FOR STOCK		ANGLES	±1/2°

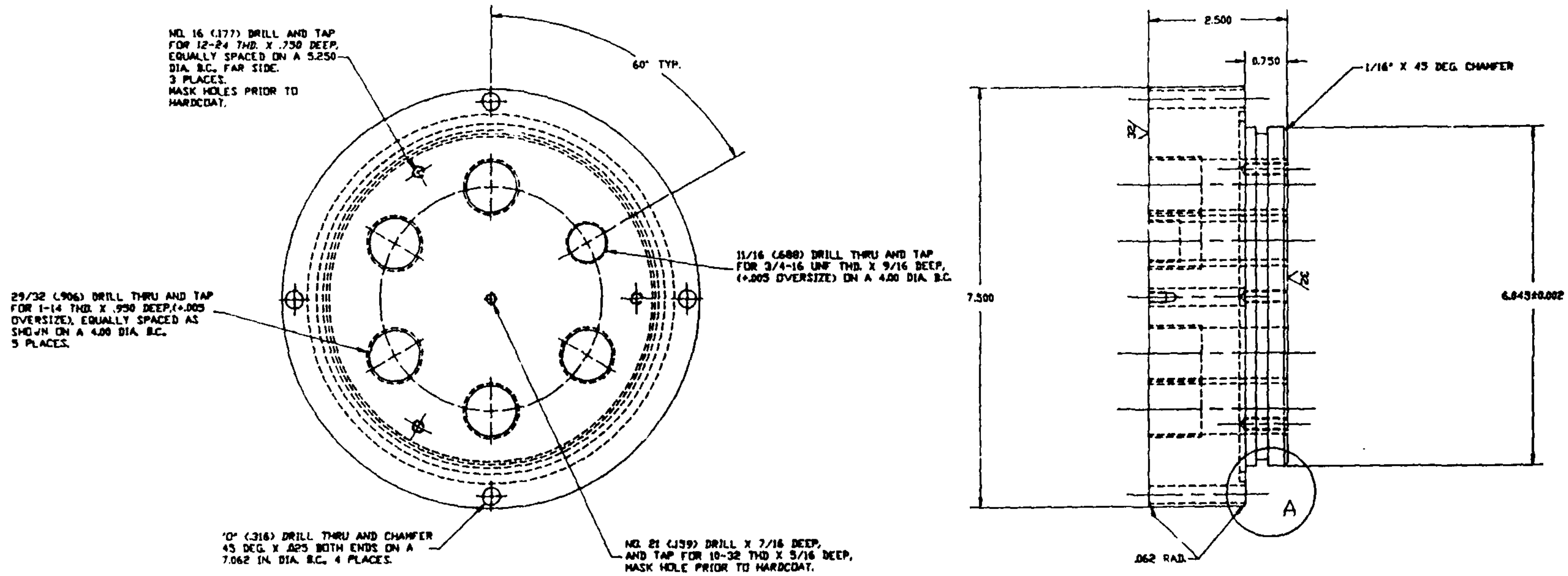
APPROVALS	SIGNATURE & DATE
DRAWN	RIA 1/29/90
CHECKED	
MECH	
ELECT	
SYSTEM	

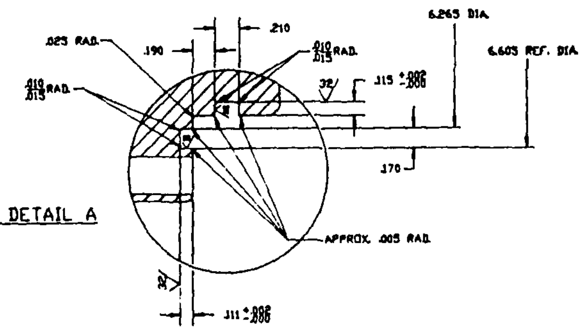
REMOVE BURRS, BREAK SHARP EDGES

WOODS HOLE OCEANOGRAPHIC INS
OCEAN SYSTEMS & MOORINGS
Ocean Engineering Departm

TITLE: STAND OFF, END PL
ENGINEERING MODU

SCALE FULL
PROJ. NO. 20/21977.00
SIZE B
DRAWING NO. 053-026



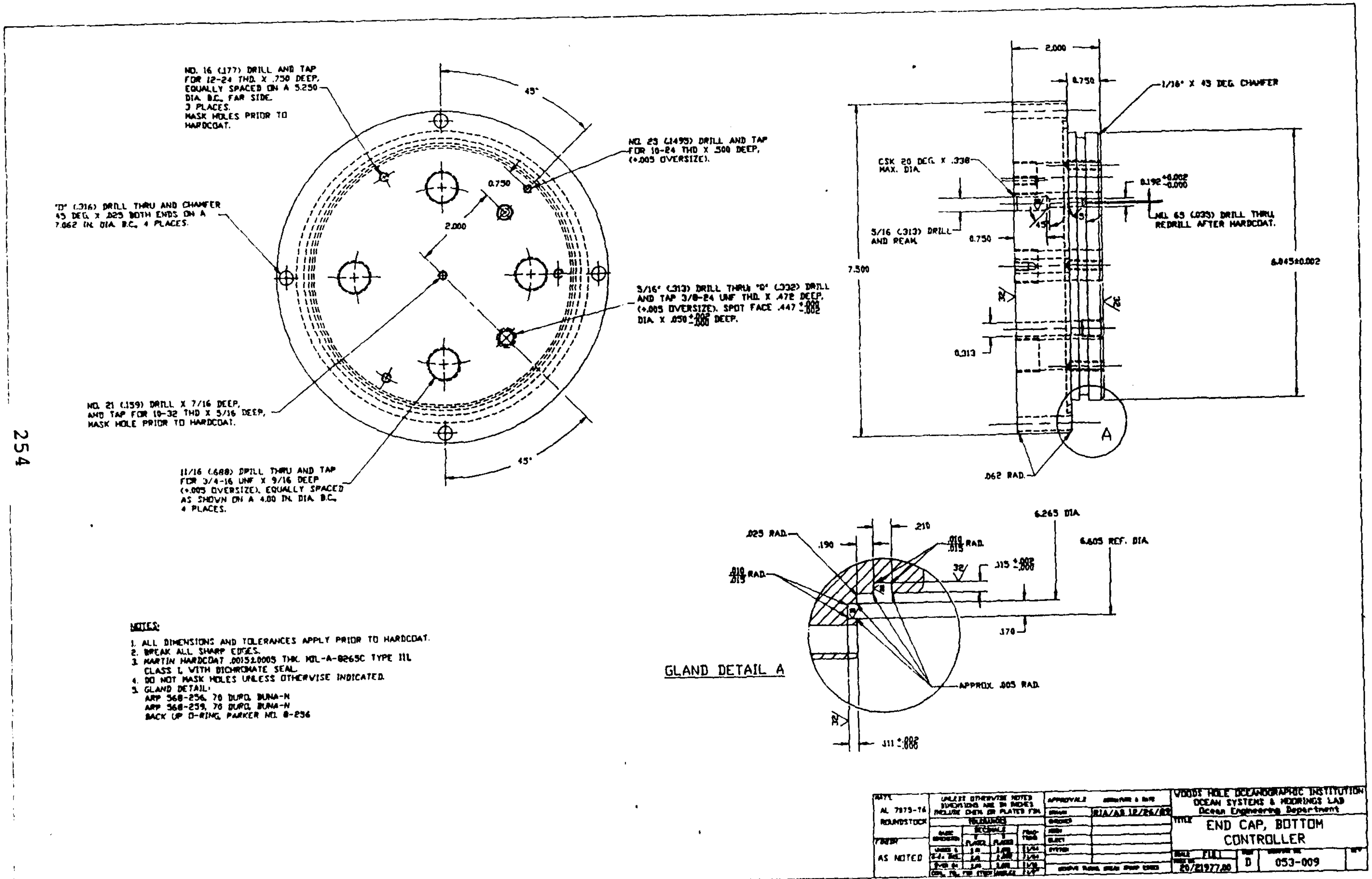


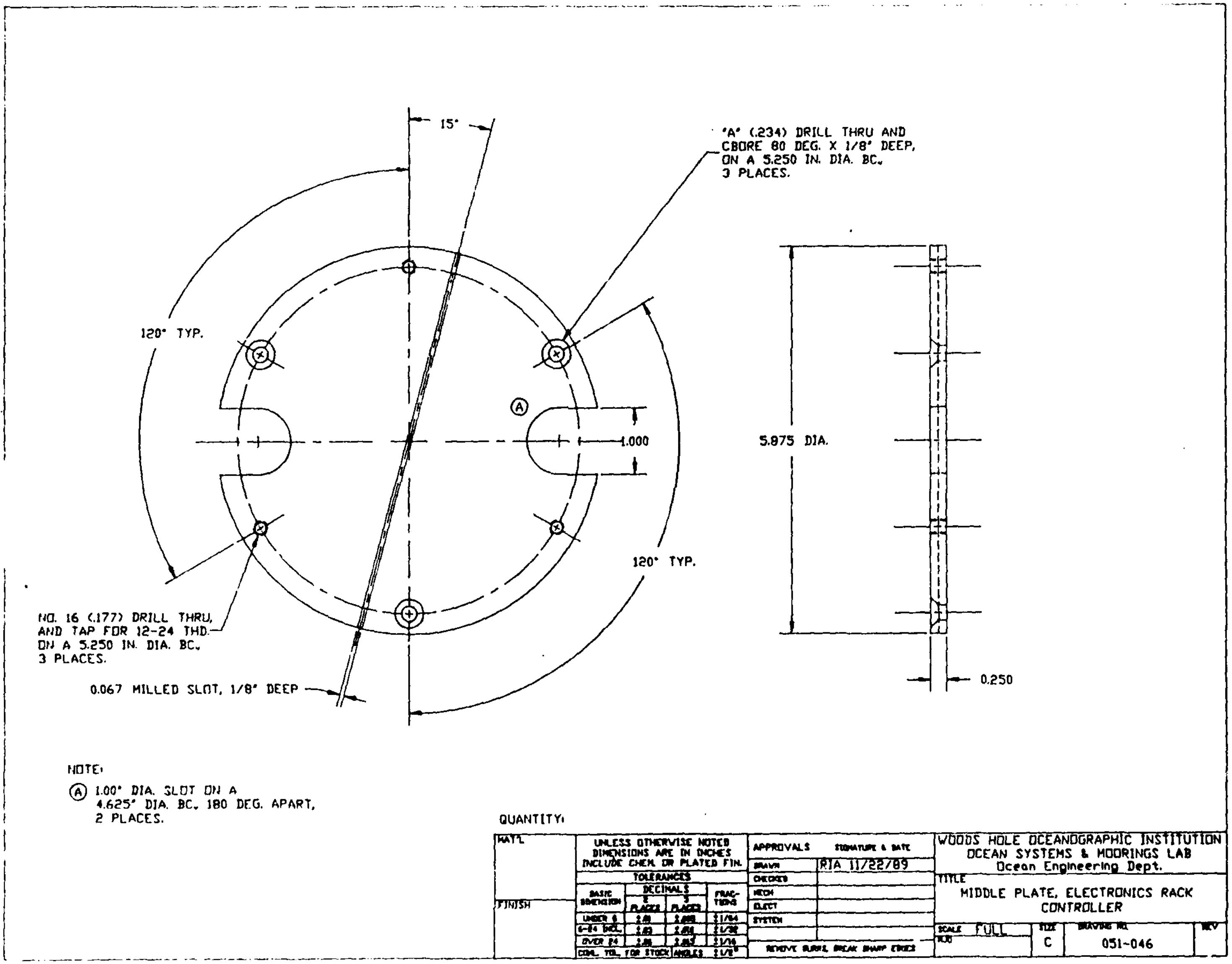
GLAND DETAIL A

NOTES:

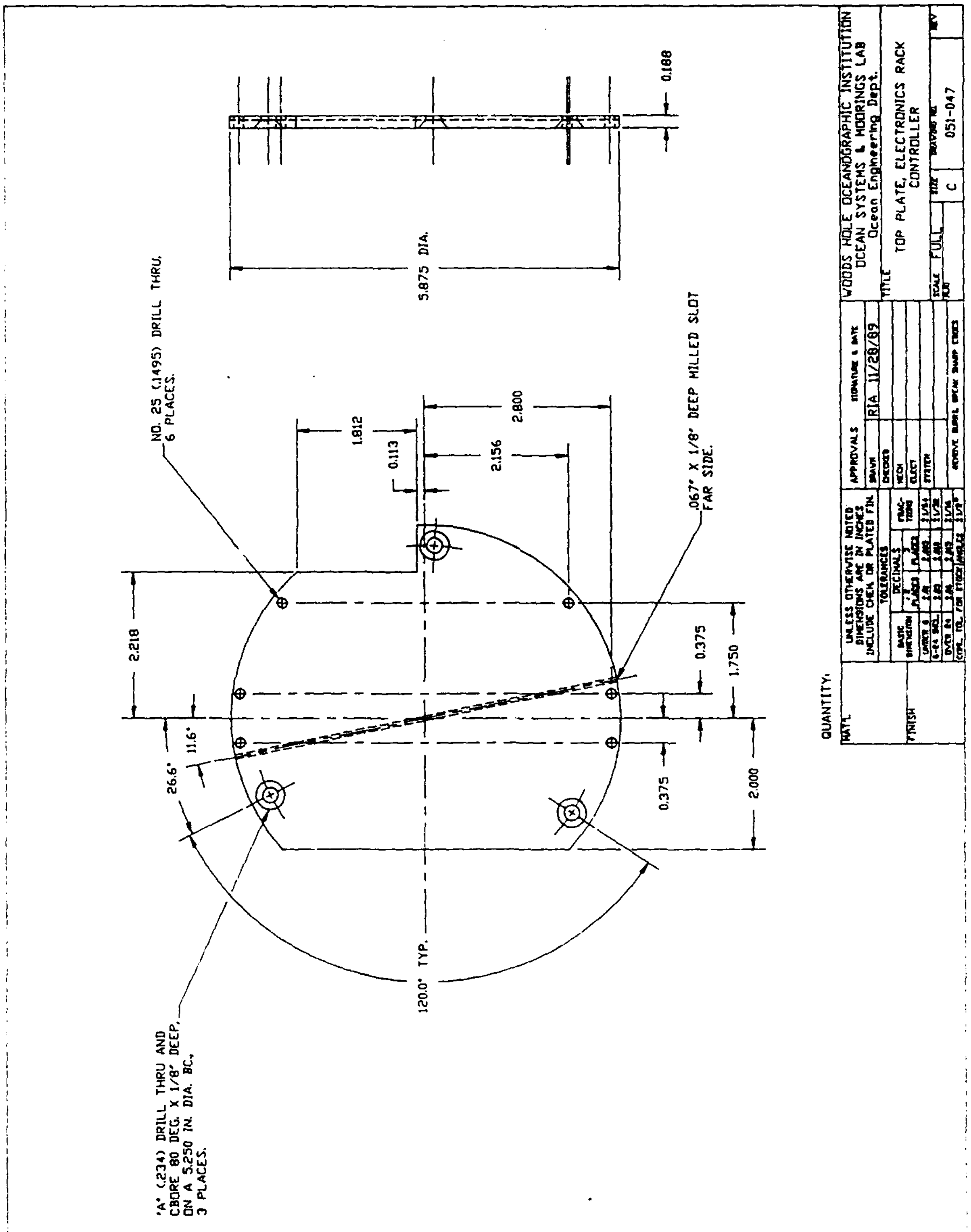
1. ALL DIMENSIONS AND TOLERANCES APPLY PRIOR TO HARDCOAT.
2. BREAK ALL SHARP EDGES.
3. MARTIN HARDCOAT .0015±.0005 THK. MIL-A-8625C TYPE III. CLASS I. WITH DICHROMATE SEAL.
4. DO NOT MASK HOLES UNLESS OTHERWISE INDICATED.
5. GLAND DETAIL:
   ARP 568-256, 70 DURO. BUNA-N
   ARP 568-259, 70 DURO. BUNA-N
   BACK UP O-RING PARKER NO. 8-236

MAT'L AL 7075-T6 ROUNDSTOCK	UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHCK OF PLATED FIN.	APPROVALS / DRAWN RIA/AB 12/19/89	WOODS HOLE OCEANOGRAPHIC INSTITUTION OCEAN SYSTEMS & MOORINGS LAB Ocean Engineering Department
FINISH AS NOTED			TITLE END CAP, TOP CONTROLLER
			SCALE FULL / SIZE D / DRAWING NO. 053-008 / 20/21977.80


NO. 16 (.177) DRILL AND TAP FOR 12-24 THD. X .750 DEEP, EQUALLY SPACED ON A 5.250 DIA. B.C., FAR SIDE. 3 PLACES. MASK HOLES PRIOR TO HARDCOAT.
45°
0.750
2.000
NO. 23 (.1495) DRILL AND TAP FOR 10-24 THD X .500 DEEP, (+.005 OVERSIZE).
"D" (.316) DRILL THRU AND CHAMFER 45 DEG. X .025 BOTH ENDS ON A 7.062 IN. DIA. B.C., 4 PLACES.
5/16" (.313) DRILL THRU "Q" (.332) DRILL AND TAP 3/8-24 UNF THD. X .472 DEEP, (+.005 OVERSIZE). SPOT FACE .447 +.000 -.002 DIA. X .050 +.002 -.000 DEEP.
NO. 21 (.159) DRILL X 7/16 DEEP, AND TAP FOR 10-32 THD X 5/16 DEEP, MASK HOLE PRIOR TO HARDCOAT.
11/16 (.688) DRILL THRU AND TAP FOR 3/4-16 UNF X 9/16 DEEP (+.005 OVERSIZE), EQUALLY SPACED AS SHOWN ON A 4.00 IN. DIA. B.C., 4 PLACES.
2.000
0.750
1/16" X 45 DEG. CHAMFER
CSK 20 DEG. X .338 MAX. DIA.
0.192 +0.002 -0.000
NO. 65 (.035) DRILL THRU. REDRILL AFTER HARDCOAT.
5/16 (.313) DRILL AND REAM.
0.750
7.500
6.845±0.002
32
0.313
.062 RAD.
A
6.265 DIA.
6.605 REF. DIA.
.025 RAD.
.190
.210
.010 .015 RAD.
.010 .015 RAD.
.315 +.002 -.000
.370
APPROX. .005 RAD.
.311 +.002 -.000
GLAND DETAIL A
NOTES:
1. ALL DIMENSIONS AND TOLERANCES APPLY PRIOR TO HARDCOAT.
2. BREAK ALL SHARP EDGES.
3. MARTIN HARDCOAT .0015±.0005 THK. MIL-A-8625C TYPE III, CLASS I, WITH BICHROMATE SEAL.
4. DO NOT MASK HOLES UNLESS OTHERWISE INDICATED.
5. GLAND DETAIL:
ARP 568-256, 70 DURO. BUNA-N
ARP 568-259, 70 DURO. BUNA-N
BACK UP O-RING, PARKER NO. 8-256
MAT'L AL 7075-T6 ROUNDSTOCK
FINISH AS NOTED
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
RJA/AB 12/26/89
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Department
TITLE END CAP, BOTTOM CONTROLLER
SCALE FULL
20/21977.00
D
053-009



15°
120° TYP.
120° TYP.
"A" (.234) DRILL THRU AND CBORE 80 DEG. X 1/8" DEEP, ON A 5.250 IN. DIA. BC., 3 PLACES.
1.000
5.875 DIA.
0.250
NO. 16 (.177) DRILL THRU, AND TAP FOR 12-24 THD. ON A 5.250 IN. DIA. BC., 3 PLACES.
0.067 MILLED SLOT, 1/8" DEEP
NOTE:
(A) 1.00" DIA. SLOT ON A 4.625" DIA. BC. 180 DEG. APART, 2 PLACES.
QUANTITY:
MAT'L
FINISH
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
APPROVALS
SIGNATURE & DATE
DRAWN RIA 11/22/89
CHECKED
MECH
ELECT
SYSTEM
REMOVE BURRS, BREAK SHARP EDGES
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept.
TITLE
MIDDLE PLATE, ELECTRONICS RACK CONTROLLER
SCALE FULL
SIZE C
DRAWING NO. 051-046
REV



NO. 25 (.1495) DRILL THRU, 6 PLACES.
1.812
0.113
2.156
2.800
.067" X 1/8" DEEP MILLED SLOT FAR SIDE.
2.218
0.375
1.750
11.6°
26.6°
0.375
2.000
120.0° TYP.
"A" (.234) DRILL THRU AND CBORE 80 DEG. X 1/8" DEEP, ON A 5.250 IN. DIA. BC, 3 PLACES.
5.875 DIA.
0.188
QUANTITY:
MAT'L
FINISH
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
DECIMALS
APPROVALS
SIGNATURE & DATE
DRAWN
RJA 11/28/89
CHECKED
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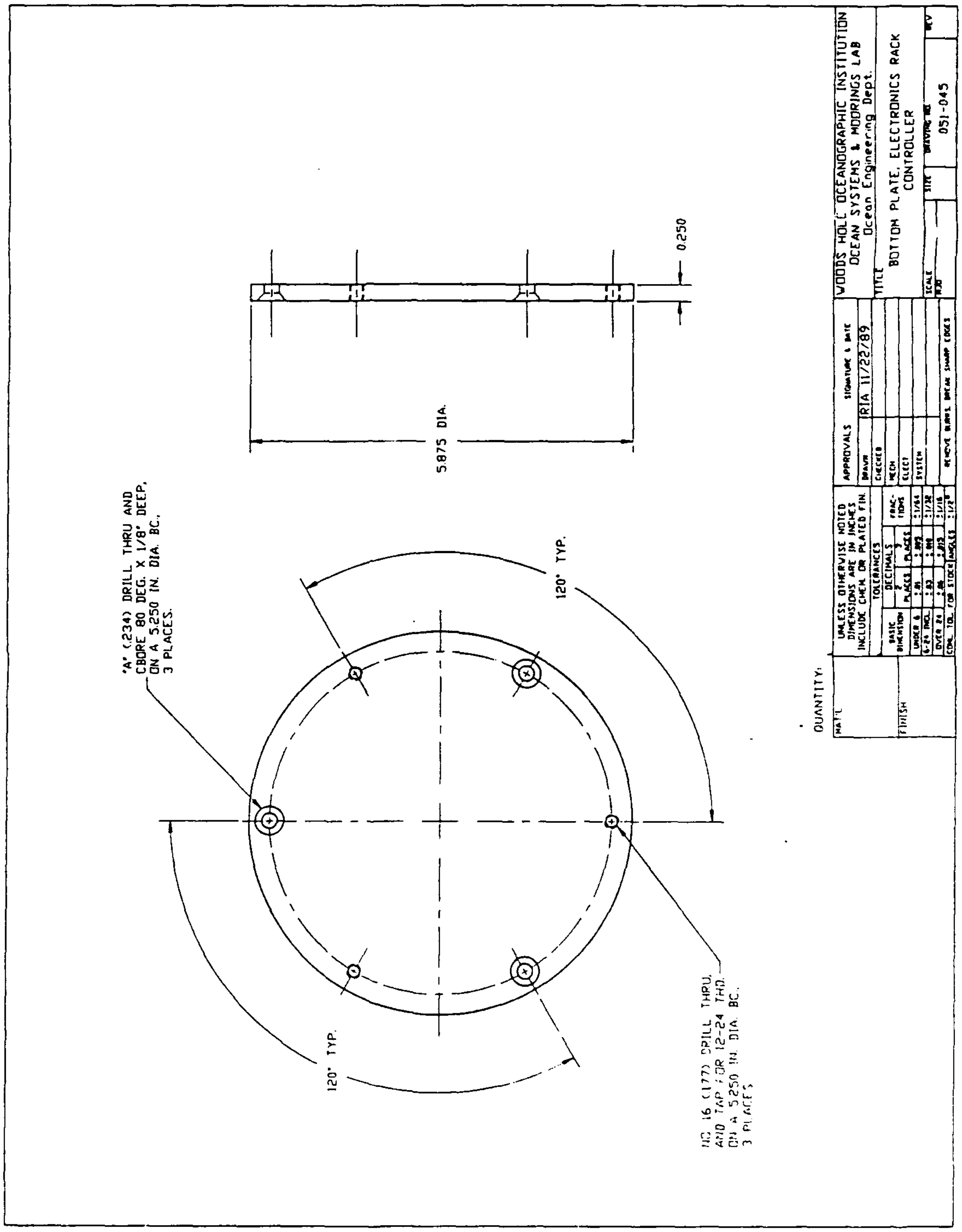
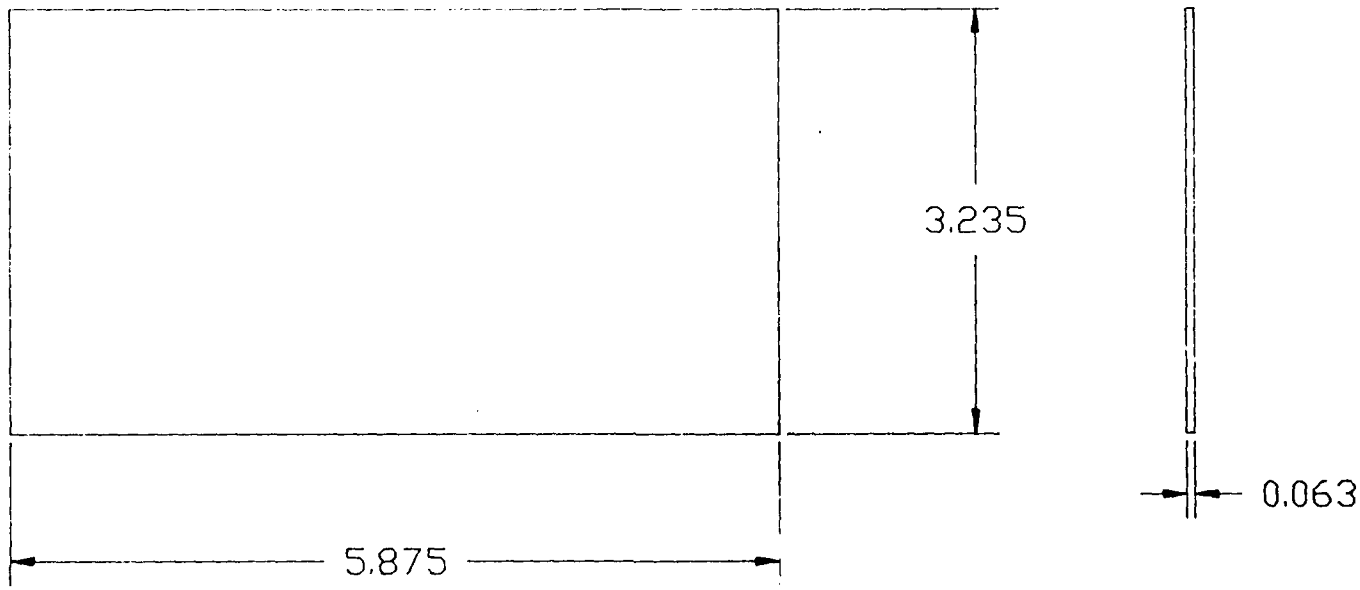
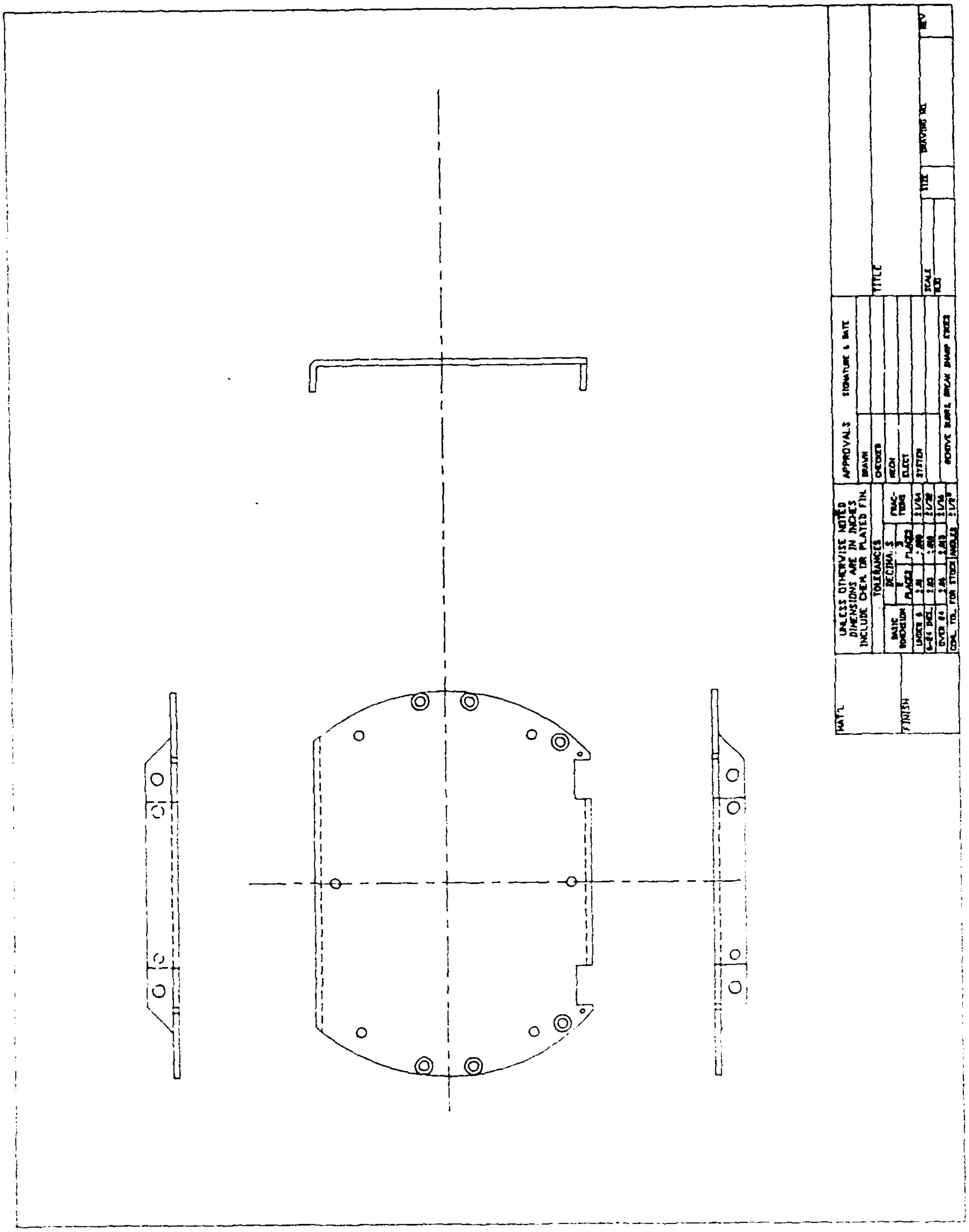
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept.
TITLE
TOP PLATE, ELECTRONICS RACK CONTROLLER
SCALE FULL
SIZE C
051-047
REV



'A' (.234) DRILL THRU AND CBORE 80 DEG. X 1/8" DEEP, ON A 5.250 IN. DIA. BC, 3 PLACES.
120° TYP.
5.875 DIA.
0.250
NO. 16 (.177) DRILL THRU AND TAP FOR 12-24 THD. ON A 5.250 IN. DIA. BC. 3 PLACES
120° TYP.
QUANTITY:
MAT'L
FINISH
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
DECIMALS
FRACTIONS
ANGLES
REMOVE BURRS, BREAK SHARP EDGES
APPROVALS
SIGNATURE & DATE
DRAWN
RIA 11/22/89
CHECKED
MECH
ELECT
SYSTEM
WOODS HOLE OCEANOGRAPHIC INSTITUTION
OCEAN SYSTEMS & MOORINGS LAB
Ocean Engineering Dept.
TITLE
BOTTOM PLATE, ELECTRONICS RACK CONTROLLER
SCALE
SIZE
DRAWING NO.
051-045
REV



MAT'L	UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES INCLUDE CHEM. OR PLATED FIN.				APPROVALS	SIGNATURE & DATE	WOODS HOLE OCEANOGRAPHIC INST OCEAN SYSTEMS & MOORINGS Ocean Engineering Dept.		
	TOLERANCES				DRAWN	RIA 11/28/89	TITLE		
	BASIC DIMENSION	DECIMALS 2 PLACES	DECIMALS 3 PLACES	FRAC-TIONS	CHECKED		VERTICAL PLATE, ELECTRONICS CONTROLLER		
FINISH	UNDER 6	±.01	±.005	±1/64	MECH				
	6-24 INCL.	±.03	±.010	±1/32	ELECT				
	OVER 24	±.06	±.015	±1/16	SYSTEM		SCALE FULL	SIZE	DRAWING NO.
	COML. TOL. FOR STOCK		ANGLES	$\pm 1/2^{\circ}$	REMOVE BURRS, BREAK SHARP EDGES		MJD	B	051-048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DIMENSIONS ARE IN INCHES
INCLUDE CHEM. OR PLATED FIN.
TOLERANCES
APPROVALS
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Integrated Seawater Sampler and Data Acquisition System Prototype: Final Report

5. Report Date April 1993

6.

7. Author(s) H.O. Berteaux, C. Eck, J. Irish, W. Jenkins, S. Kery, C. Albro and S. McDowell

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Woods Hole, Massachusetts 02543

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15. Supplementary Notes

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16. Abstract (Limit: 200 words)

This report documents the work performed by the Woods Hole Oceanographic Institution (WHOI) and the Battelle Memorial Institute from August 1988 to December 1992 in the NSF sponsored development of an Integrated Seawater Sampler and Data Acquisition Prototype. After a 6-month initial design study, a prototype underwater profiling unit was designed and constructed, containing the water acquisition subsystem, CTD and altimeter, control circuitry and batteries. A standard WHOI CTD was adapted for use in the underwater unit and was interfaced to the underwater controller which had a telemetry module connecting it with a deck control unit. This enabled CTD data to be logged in normal fashion on shipboard while additional commands and diagnostics were sent over the telemetry link to command the underwater unit's water sampling process and receive diagnostic information on system performance.

The water sampling subsystem consisted of 36 trays, each containing a plastic sample bag, the pump and control circuitry. The sample bags, initially sealed in a chemically clean environment, were opened by pumping the water out of the tray, thus forcing water into the bag by ambient pressure. The command system could select any bag, and control the water sampling process from the surface with diagnostic information on system altitude, depth, orientation and cable tension displayed in real time for operator information.

At sea tests confirmed the operation of the electrical and control system. Problems were encountered with the bags and seals which were partially solved by further post cruise efforts. However, the bag closing mechanism requires further development, and numerous small system improvements identified during the cruises need to be implemented to produce an operational water sampler. Finally, initial design for a water sampler handling and storage unit and water extraction system were developed but not implemented. The detailed discussion of the prototype water sampler design, testing and evaluation, and new bag testing results are presented.

17. Document Analysis a. Descriptors

sea water sampler
shipboard profiling system
chemical free sample bags

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
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